Three-month pulmonary function and radiological outcomes in COVID-19 survivors: a longitudinal patient cohort study

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Abstract

Background: This study aimed to investigate pulmonary function and radiological outcomes in a group of coronavirus disease 2019 (COVID-19) survivors.

Methods: 172 COVID-19 survivors in a follow-up clinic in a referral hospital underwent high resolution computed tomography (CT) of the thorax and pulmonary function tests at three month after hospital discharge.

Results: The median duration from hospital discharge to radiological and pulmonary function test was 90 (interquartile range=88-95) days. The abnormal pulmonary function was found in 11 (6.40%) patients, and abnormal small airway function ($FEF_{25-75\%}$) in 12 (6.98%). Six (3.49%) patients had obstructive ventilation impairment and six (3.49%) had restrictive ventilatory impairment. No significant differences in lung function parameters were observed between the non-severe and severe groups. Of 142 COVID-19 patients performed CT scan, 122 (85.91%) showed residual CT abnormalities and 52 (36.62%) showed chronic and fibrotic changes. The ground-glass opacities absorption in the lungs of severe cases was less satisfactory than that of non-severe patients. The severe paients had higher CT scores than non-severe cases (2.00 versus 0.00, $P < 0.001$)

Conclusion: Of the COVID-19 survivors, 6.40% still present pulmonary function abnormality three month after discharge, which did not vary by disease severity during hospitalization. 85.91% patients had abnormalities on chest CT, with fibrous stripes and ground glass opacity as the most common pattern.

Keywords: COVID-19; SARS-Cov-2; Pulmonary function assessment;

Introduction

Coronavirus disease 2019 (COVID-19) is new respiratory illness that can cause serious pneumonia and lung failure [1]. The World Health Organization (WHO) declared COVID-19 a public health emergency of international concern on January 30, 2020 and this pandemic quickly spread globally to more than 200 countries. This novel disease has triggered enormous human casualties and serious economic loss around the globe [2]. Due to its highly contagious nature, there are few data describing pulmonary function in the acute phase of the disease. Evaluation of lung function in recovered patients will enable better understanding of the prognostic characteristics of COVID-19 [3].

As of July 7, 2020, we found three studies describing the pulmonary function of COVID-19 patients at or after hospital discharge [4-6]. One on 110 COVID-19 patients showed that at discharge, the abnormal spirometry parameters ranged from 4.5% to 47.2% [4]. The other including eighteen COVID-19 patients showed that 39% of them suffered from pulmonary impairments one month after rehabilitation and discharge [5]. Another study reported clinical manifestation of lung function and chest radiology in two critically ill patients with COVID-19 three month from onset [6], with the younger patient (aged 20 years) recovered completely on both radiology and pulmonary function tests, whereas the older patient showed residual radiological changes and impaired lung function.

As the above two studies with follow-up for more than one month after discharge were small in size (i.e., only two and eighteen patients included), we hereby evaluated the radiology and pulmonary function of a larger sample of COVID-19 patients with a longer follow-up. Our study aims at, firstly, describing characteristics of radiology and pulmonary function in a larger sample of COVID-19 patients with a longer follow-up, and secondly, evaluating the results of chest CT and pulmonary function by baseline disease severity.All patients were recruited from the only referral hospital in one of the largest cities in China, Shenzhen. Awareness of characteristics of radiology and pulmonary function at three-month after discharge may enable better understanding of the prognosis of COVID-19 patients.

Methods

Study Design and Participant Criteria

Our study consisted of 172 consecutively hospitalized patients from January 11, 2020 to February 21, 2020 at the Third People's Hospital of Shenzhen. The Third People's Hospital of Shenzhen is the only referral hospital authorized by the government in Shenzhen to care and treat patients with COVID-19. The COVID-19 was diagnosed according to the WHO interim guidance [7]. All patients were followed until June 13, 2020. Data obtained from electronic medical records included epidemiological, clinical, laboratory, and radiological information as well as the treatment and progression of the disease. Information of the confirmed COVID-19 patients was collected by nurses, physicians, or other medical staff at the hospital.

Patient Consent Statemen

This study was approved by the ethics committee of The Third People's Hospital of Shenzhen (IRB No. 2020 108). All participants have signed informed consent. It was not appropriate or possible to involve patients or the public in the design, conduct of our research.

Confirmation of COVID-19

The Real-Time Reverse Transcription Polymerase Chain Reaction method was applied to detect the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [8]. Two pairs of primers targeting the open reading frame 1ab (ORF1ab) and the nucleocapsid protein (N) were amplified and examined. The corresponding sequences for ORF1ab were 5'-CCCTGTGGGTTTTACACTTAA-3' (F), 5'-ACGATTGTGCATCAGCTGA-3' (R), and 5'-CY3-CCGTCTGCGGTATGTGGAAAGGTTATGG-BHQ1-3′ (probe), and those for N were 5'-GGGGAACTTCTCCTGCTAGAAT-3' (F), 5'-CAGACATTTTGCTCTCAAGCTG-3' (R), and 5'-FAM-TTGCTGCTGCTTGACAGATT-TAMRA-3′ (probe). Each sample was run in triplicate with both positive and negative control sets. The identification process strictly complied the diagnostic criteria recommended by the National Centers for Disease Control and Prevention of China (China CDC). The key laboratory of the Shenzhen CDC reconfirmed the samples with positive results for COVID-19.

Severity of COVID-19 patients

According to the national guidelines for community-acquired pneumonia and the diagnosis and treatment plan for COVID-19 in China [9, 10], patients were assigned to severe or mild group based on the results from chest radiography, clinical examination and symptoms. Those with mild symptoms, such as fever, cough, expectoration, and other upper respiratory tract symptoms, but normal radiological images, or with mild changes on chest radiography, were identified as non-severe cases [11]. The degree of radiological change was differentiated by multiple small patchy shadows and interstitial changes, mainly in the outer zone of the lung and under the pleura. Severe pneumonia was diagnosed by any of the following conditions: 1) significantly increased respiration rate (RR): RR ≥ 30 times/minute; 2) hypoxia: oxygen saturation (resting state) ≤ 93%; 3) blood gas analysis: partial pressure of oxygen/fraction of inspired oxygen ($PaO_{2)}$ /$FiO_{2)}$≤300 mmHg (millimetres of Mercury); or 4) the occurrence of respiratory or other organ failure that requires intensive care unit (ICU) monitoring and treatment, or shock.

Follow-up examination for radiology and pulmonary function assessment

Of the patients returned for follow-up examination three month after discharge, all were invited to have chest computerized tomography (CT) scan. Results of the CT scans were evaluated by radiology experts with the severity status marked. In addition, these patients had a normal oxygen saturation and the results of six-minutes walking test were normal. They were evaluated the lung function using spirometry to obtain relevant indices including first second exhalation volume (FEV_1), forced vital capacity (FVC), FEV_1/FVC%, forced expiratory flow rate at 50% and 75% of FVC ($FEF_{50\%}$, $FEF_{75\%}$), forced expired flow at 25-75% of FVC ($FEF_{25-75\%}$), inspiratory reserve volume (IRV), tidal volume (TV) and expiratory reserve volume (ERV).

Statistical Analysis

All data were analysed by R version 4.0.2 software (R Core Team, Vienna, Austria). The qualitative variables were described as frequency and percentages, and the quantitative variables as mean and standard deviation, or median and interquartile range (IQR) if they did not follow a normal distribution. For quantitative data that were normally distributed, independent group *t*-tests was performed to compare the means; otherwise, the Mann-

Whitney test was used. Qualitative data were compared using the χ^2 test or the Fisher exact test, if the counts were small. A 2-sided α of less than 0.05 was considered statistically significant.

Results

A total of 172 confirmed COVID-19 patient admitted to the Third People's Hospital of Shenzhen from January 11, 2020 to February 16, 2020 and followed until June 13, 2020 were included. The baseline (i.e., at hospitalization) characteristics by disease severity were shown in the Supplementary Table 1. Patients who were older, smoker, had fever, chronic obstructive pulmonary disease (COPD), need ICU care, invasive ventilatory support and non-invasive ventilatory support tended to develop severe COVID-19 (P from <0.001 to 0.02). Moreover, the length of hospitalization was significantly longer in severe group than that of non-severe group (P <0.001). The duration from discharge to PFTs was also longer in patients with non-severe disease than that of severe patients (40 ± 11.6 versus 34.7 ± 16.5 days).

All patients evaluated pulmonary function by spirometry. The symptom profiles at follow-up were shown in the Supplementary Table 2, which shown no significant differences between the non-severe and severe groups. The median (IQR) age of the patients was 47.50 (28-67) years. Of the 172 patients, the median (IQR) of FEV_1, FVC and FEV_1/FVC% was 104.70 (96.78-113.76), 128.49 (119.20-139.49) and 81.39 (77.33-85.09), respectively, with younger patients showing significantly lower FEV_1 % pred and FVC % pred, and higher FEV_1/FVC than older age groups (P = 0.002, 0.003 and <0.001, respectively). Patients who smoked had significantly lower FEV_1 % pred and FVC % pred (p=0.04 and 0.03, respectively). Underweight patients had lower FVC % pred and higher FEV_1/FVC% than patients with higher BMI (P=0.01 and 0.001, respectively). Furthermore, FVC % pred was significantly higher in patients with hypertension or headache as initial symptoms (both P=0.03), but lower in those had fever as initial symptoms (P= 0.04). Patients who had cough as initial symptoms showed higher FEV_1/FVC% (P=0.03), but lower in those who used lopinavir/ritonavir drugs (P= 0.03) (Table 1).

Table 1 Characteristics of 172 patients with SARS-CoV-2/COVID-19 by lung function at 3 months follow-up after hospital discharge

At three months from discharge, ten (7.19%) of the non-severe cases and one (3.03%) of the severe cases had abnormal pulmonary function. Of those with anomalies in pulmonary function tests, six (3.59%) had abnormal FEV_1 % pred, four (2.38%) had abnormal FVC % pred and six (3.55%) had abnormal FEV_1/FVC%. Regarding the FEF, 13 (7.56%) patients were in $FEF_{50\%}$, two (1.16%) in $FEF_{75\%}$ and 12 (6.98%) in $FEF_{25-75\%}$. Of the 139 patients with non-severe COVID-19, six (4.79%) had obstructive ventilation impairment and five (3.73%) had restrictive ventilatory impairment. Furthermore, one (3.12%) patient in the severe group had restrictive ventilatory impairment at three months after discharge. No significant differences in levels of FEV_1 pred, FVC pred and FEV_1/FVC% were observed between the non-severe and severe groups (Table 2). The median (IQR) values of IRV (L), TV (L) and ERV (L) were 1.19 (0.83-1.67), 1.11 (0.91-1.36) and 1.17 (0.79-1.62), respectively, with no significant differences between the non-severe and severe groups being observed (Table 2).

Table 2 Pulmonary function of 172 COVID-19 patients by disease severity at 3 months follow-up after hospital discharge

Of the patients returned for follow-up examination three months after discharge, 142 (82.56%) had chest CT scans. The severe patients had higher CT score than non-severe cases (2.00 versus 0.00, $P < 0.001$). Of them, 122 (85.91%) had residual CT abnormalities and 52 (36.62%) showed chronic and fibrotic changes. The ground-glass opacities (GGO) in the lung were completely absorbed in 77 (54.23%) patients, partially absorbed in 64 (45.07) patients, and increased in one severe case. Severe cases showed higher rates of residual CT abnormalities (i.e., GGO) in the lungs than non-severe cases (76.67% versus 37.50%, $P = 0.004$) (Table 3).

Table 3 Radiological outcome of 142 COVID-19 patients by disease severity at 3 months follow-up after hospital discharge

Supplement Figure 1 shows the CT scans of a patient with non-severe COVID-19. The GGO in the right upper lobe of the lung at admission changed towards disappeared at discharge, further absorbed one month after discharge, and completely absorbed three month after discharge. Supplement Figure 2 shows the CT scans of a severe COVID-19 patient. Lung consolidation in the inferior lobes could be seen at admission. The right lower lobe consolidation was large and air bronchogram was found. The lesion was completely absorbed before discharge with mild GGO remained. The GGO in the lungs was completely absorbed at one month and three month after discharge, without bronchial dilatation in the bronchial tubes (Supplement Figure 2).

Discussion

In this study, we comprehensively described the characteristics of radiology and pulmonary function tests in COVID-19 patients three month after hospital discharge using data from a designated hospital in Shenzhen, China. Of 172 COVID-19 patients evaluated the lung function three month after discharge, we found that only six (3.59%) patients had obstructive ventilation impairment and six (3.55%) had restrictive ventilatory impairment. The pulmonary function tests showed no differences between the severe and non-severe cases. Of 142 COVID-19 patients had chest CT scan, 122 (85.91%) still had residual CT abnormalities and 52 (36.62%) had chronic and fibrotic changes. Severe cases had higher rate of residual CT abnormalities than non-severe patients (presence of GGO was 76.67% versus 37.50%).

The prevalence of pulmonary function abnormality in our study was lower than that in previously studies [5], which may be attributable to different time of measurement, suggesting that lung function might be continuously improved after discharged and is unlikely to cause a lifelong impairment [12, 13]. It has been reported that patients with COVID-19 still suffered from pulmonary dysfunction during the recovery period [14]. One of the two recent studies including 18 patients who recovered from COVID-19 showed that abnormal pulmonary function at discharge manifested in five (41.7%) non-severe and two (33.3%) severe patients [5]. Another study of two COVID-19 patients who were discharged from hospital found that the older case had residual radiological changes and impaired lung function during the 3-month follow-up period [6]. In our study, of the 172 COVID-19 patients assessed pulmonary function three month after discharge, patients aged less than 10 years had restrictive ventilation impairment, which may be partly due to the low compliance during the spirometry test. Moreover, in accordance with previous studies, we showed that abnormal pulmonary function

was, as expected, mainly manifested in patients aged >50 years, because pulmonary function naturally decline with aging, as indicated by the decreases in elasticity and function of lung tissue as well as the muscle strength [15, 16].

Moreover, similar fibrotic changes were observed in patients with SARS, which may not eventually cause lifelong pulmonary damage because it seems to have the ability of self-rehabilitation and gradual improvements were observed over time [17-19]. Therefore, periodic and regular long-term follow-up studies are warranted to evaluate the changes in lung function for COVID-19 patients.

As CT is more sensitive in detecting lung abnormalities than chest x-ray, the abnormality rate was higher than that from pulmonary tests. In COVID-19 survivors after discharge, 85.91% patients still had residual CT abnormalities, and 36.62% patients showed chronic and fibrotic changes. A recent study suggested that COVID-19 survivors with residual chest CT abnormalities might progress to pulmonary fibrosis, especially in severe cases [20]. In our study, of the COVID-19 patients discharged from rehabilitation, 54.23% had complete absorption of GGO in the lungs, indicating that with effective antiviral treatment during hospitalization and improvement of self-immunity after discharge, the lesions in both lungs could be improved significantly. Moreover, the GGO progression in one severe patient reflected a less satisfactory absorption of GGO in severe COVID-19 patients, which calls for more efficient therapeutic strategies to protect severe patients from a long-term lung damage.

This study has several limitations. First, due to the limited number of confirmed COVID-19 patients from a city outside the epidemic centres, sample size of the present study is limited. However, this study has provided the best comprehensive evidence to date showing the results of pulmonary function tests by spirometry and radiology in the COVID-19 patients three month after hospital discharge. Second, due to the lack of pulmonary function tests at admission or during hospitalization, we did not assess the changes in pulmonary function tests or CT scans. In our study, no patients developed chronic lung disease, which might be reasonable to presume that their basic lung function was normal. However, longer follow-up examinations to evaluate the longer-term recovery of lung function are necessary. Third, FEV_1 and FVC were lower in younger COVID-19 patients (i.e.,

<10 years old) than adults, which may be due to the difficulties in performing a forceful expiratory manoeuvre to derive reliable spirometry results in young children. Thus the pulmonary function of the young patients could be underestimated.

In conclusion, at three month after discharge, of 172 COVID-19 survivors, 11 (6.40%) present abnormalities in pulmonary function tests, and 85.91% in chest CT scans, with fibrous stripes and ground glass opacity as the most common pattern. Further studies with longer follow-up to evaluate the long-term changes in pulmonary function and radiology are warranted.

Contribution statement

HY and LL conceptualized and designed the study and had full access to all data in the study. They take responsibility for the integrity of the data and the accuracy of the data analysis. LX, WY, HY, LL and XL contributed to the writing of the report. LX, HZ, MZ, ZL and YY contributed to the critical revision of the report. WY, CQ, and XL contributed to the statistical analysis. All authors contributed to the data acquisition, data analysis, or data interpretation, and reviewed and approved the final version.

Conflicts of Interest

All authors declare no competing interests.

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Characteristics	Pulmonary ventilation function					
	FEV_1 % pred*	P value	FVC% pred#	P value	FEV_1/FVC%&	P value
Median (IQR)	104.70 (96.78-113.76)		128.49 (119.20-139.49)		81.39 (77.33-85.09)	
Age, year, Median (IQR)						
<10	59.86 (57.37-63.89)		64.48 (60.11-71.39)		90.83 (87.61-94.97)	
10-19	109.7 (109.3-114.1)		123.90 (120.4-127.9		88.47 (86.21-91.34)	
20-29	101.64 (94.38-114.58)	0.002	119.60 (113.9-126.4	0.003	84.11 (76.91-90.06)	<0.001
30-49	106.32 (98.26-114.58)		130.46 (121.78-140.36)		82.24 (78.18-86.04)	
≥50	101.38 (95.02-153.82)		128.99 (118.27-140.85)		79.80 (76.18-83.73	
Gender, Median (IQR)						
Female	106.45 (97.2-114.67)	0.26	128.49 (118.84-138.93)	0.98	81.79 (78.28-86.31)	0.34
Male	102.23 (96.33-111.77)		128.32 (119.4-140.51)		81.05 (76.88-85.88)	
BMI, kg/m^2, Median (IQR)						
Underweight	101.01 (70.46-106.34)		116.50 (76.55-120.79)		88.08 (87.3-93.5)	
Normal	106.51 (97.13-114.18)	0.32	128.97 (122.1-139.78)	0.01	81.45 (77.24-85.13)	0.001
Overweight	102.55 (97.22-112.34)		130.50 (119.7-143.1)		79.99 (76.70-84.65)	
Obesity	99.84 (90.19-112.72)		126.76 (108.82-135.28)		83.94 (78.03-86.53)	
Smoke, Median (IQR)$						

No	106.67 (97.57-117.45)	0.04	128.99 (121.92-139.13)	0.03	82.07 (78.56-85.98)	0.05
Yes	89.90 (87.35-92.44)		97.44 (91.74-103.15)		92.97 (90.10-92.97)	
Epidemiological information, Median (IQR)						
From Hubei	106.50 (97.03-114.3)		128.9 (119.4-143.63)		81.21 (76.67-85.66)	
Not been to Hubei, but infected by individuals from Hubei	102.94 (96.61-111)	0.59	126.42 (117.69-137.39)	0.38	83.09 (78.05-86.26)	0.33
Without any clear contact history	105.27 (95.57-113.86)		130.00 (120-134.9)		81.12 (76.58-84.93)	
Personal disease history, Median (IQR)						
Hypertension						
No	103.62 (96.6-113.07)	0.20	127.11 (119.17-138.48)	0.03	81.79 (77.46-86.02)	0.15
Yes	107.55 (101.33-114.89)		137.56 (128.02-148.59)		78.47 (76.17-83.68)	
Cardiovascular disease						
No	104.32 (96.69-113.79)	0.56	127.82 (118.68-139.26)	0.10	81.88 (77.55-85.95)	0.13
Yes	106.69 (97.07-113))		132.40 (127.7-147.53)		77.32 (74.50-84.86)	
Liver disease						
No	104.73 (96.97-113.79)	0.91	128.49 (119.26-139.49)	0.56	81.30 (77.33-85.95)	0.69
Yes	104.70 (94.38-111.29)		127.80 (117.42-138.41)		84.13 (77.58-85.89)	
COPD						
No	104.76 (97.06-113.85)	0.30	128.77 (119.22-139.46)	0.60	81.61 (77.40-85.93)	0.20

Yes	96.61 (88.22-110.23)		122.31 (116.34-138.65)		78.29 (64.91-82.59)	
Initial symptoms, Median (IQR)						
Fever						
No	106.66 (98.38-114.49)	0.10	131.72 (121.61-144.20)	0.04	81.58 (76.41-84.94)	0.52
Yes	102.15 (96.48-112.08)		126.60 (117.08-138.48)		81.28 (77.46-86.17)	
Cough						
No	102.23 (96.58-111.98)	0.16	127.82 (119.15-127.97)	0.62	80.99 (76.25-85.05)	0.03
Yes	107.55 (97.31-114.82)		128.99 (119.51-139.52)		82.81 (78.78-85.97)	
Headache						
No	104.02 (96.61-113.69)	0.33	127.87 (118.84-138.99)	0.03	81.77 (77.42-85.92)	0.07
Yes	111.54 (107.34-113.74		141.40 (135.4-146.2)		77.05 (70.19-79.03)	
Diarrhea						
No	104.83 (97.00-113.76))	0.28	128.67 (119.23-139.49)	0.34	81.39 (77.33-85.89)	0.77
Yes	96.15 (91.58-102.42)		117.30 (108.10-130.30)		79.70 (77.28-83.28)	
Fratigue						
No	104.32 (96.69-113.79)	0.28	127.88 (139.52-118.94)	0.52	81.35 (77.33-85.95)	0.73
Yes	106.81 (106.45-109.48)		130.60 (128.40-135.20)		81.77 (81.22-82.77)	
Treatment, N (%)						
Lopinavir/ritonavir						
No	108.44 (97.55-116.98)	0.03	132.27 (121.49-140.14)	0.12	82.53 (77.34-86.52)	0.24

Yes	102.15 (96.48-111.10)		126.42 (117.80-139.32)		81.12 (77.39-85.48)	
Favipiravir						
No	104.67 (96.69-113.79)	0.70	128.58 (119.18-139.42)	0.90	81.30 (77.33-85.90)	0.54
Yes	106.18 (103.62-110.08)		122.40 (121.03-148.10)		84.68 (83.68-85.13)	
Need ICU care						
No	105.48 (96.69-113.90)	0.22	128.77 (119.25-139.52)	0.21	81.35 (77.83-85.95)	0.98
Yes	97.23 (97.06-98.46)		116.90 (116.60-127.40)		83.23 (79.92-83.70)	
Invasive ventilatory support						
No	104.76 (96.61-113.85)	0.74	128.58 (119.23-139.46)	0.51	81.35 (77.32-85.93)	0.72
Yes	98.32 (97.69-105.45)		116.90 (116.80-128.90)		83.23 (81.58-83.72)	
Non-invasive ventilatory support						
No	105.48 (96.86-113.85)	0.38	128.58 (119.23-139.46)	0.43	81.35 (77.34-85.93)	0.63
Yes	98.32 (92.17-106.98)		127.3.8 (110.51-136.13)		83.70 (78.62-85.05)	

SARS-CoV-2, Severe acute respiratory syndrome coronavirus 2; COVID-19, Coronavirus disease 2019; IQR, Interquartile-range; FEV_1, Forced expiratory volume in one second; FVC, Forced vital capacity; BMI, Body mass index; COPD, chronic obstructive pulmonary disease;

* Five missing values were excluded here only; # Four missing values were excluded here only; & Three missing values were excluded here only; $ Eighty-eight missing values were excluded here.

Table 2 Pulmonary function of 172 COVID-19 patients by disease severity at 3 months follow-up after hospital discharge

Characteristics	Disease severity			P value
	Non-severe	Severe	Total	
Number (%)	139 (80.81)	3 3(19.19)	172	
Pulmonary ventilation function				
FEV_1 % pred*, Median (IQR)*	106.45 (97.18-113.87)	98.47 (94.86-112.11)	104.70 (96.78-113.76)	0.18
FEV_1 % pred*, n (%) <80%*	5 (3.73)	1 (3.12)	6 (3.59)	1.00
FVC % pred#, Median (IQR)#	128.91 (120.02-139.58)	125.83 (114.09-134.28)	128.49 (119.20-139.49)	0.08
FVC % pred#, n (%) <80%#	4 (2.92)	0 (0.00)	4 (2.38)	0.76
FEV_1/FVC%&, Median (IQR)&	81.12 (76.45-85.94)	83.45 (79.40-85.85)	81.39 (77.33-85.09)	0.14
FEV_1/FVC%&, n (%) <70%&	6 (4.79)	0 (0.00)	6 (3.55)	0.50
Small airway function				
Abnormal $FEF_{25-75\%}$, n (%)	12 (8.63)	0 (0.00)	12 (6.98)	0.17
Abnormal $FEF_{50\%}$, n (%)	12 (7.10)	1 (3.03)	13 (7.56)	0.47
Abnormal $FEF_{75\%}$, n (%)	2 (1.44)	0 (0.00)	2 (1.16)	1.00
Lung volumes				
IRV, Median (IQR), L	1.20 (0.81-1.70)	1.17 (0.99-1.51)	1.19 (0.83-1.67)	0.86
TV , Median (IQR), L	1.13 (0.91-1.37)	1.06 (0.88-1.28)	1.11 (0.91-1.36)	0.69
ERV, Median (IQR), L	1.21 (0.79-1.65)	1.02 (0.88-1.42)	1.18 (0.79-1.62)	0.22

SARS-CoV-2, Severe acute respiratory syndrome coronavirus 2; COVID-19, Coronavirus disease 2019; IQR, Interquartile-range; FEV_1, Forced expiratory volume in one second; FVC, Forced vital capacity; FEF, Forced expiratory flow rate; IRV, Inspiratory reserve volume; TV, Tidal volume; ERV, Expiratory reserve volume;

* Five missing values were excluded here only; # Four missing values were excluded here only; & Three missing values were excluded here only;

Table 3 Radiological outcome of 142 COVID-19 patients by disease severity at 3 months follow-up after hospital discharge

Characteristics	Disease severity			P value
	Non-severe	Severe	Total	
Number (%)	112 (78.87)	30 (21.13)	142	
CT score, Median (IQR)	0.00 (0.00-2.00)	2.00 (2.00-2.00)	0.00 (0.00-2.00)	<0.001
CT changes, n (%)				
Normal				
Yes	17 (15.18)	3 (10.00)	21 (14.08)	0.62
No	95 (84.82)	27 (90.00)	122 (85.91)	
Chronic and fibrotic changes				
Yes	41 (36.61)	12 (40.00)	52 (36.62)	0.84
No	71 (63.39)	18 (60.00)	90 (63.38)	
Ground-glass opacity (GGO)				
Complete absorption	70 (62.50)	7 (23.33)	77 (54.23)	0.004
Partial absorption	42 (37.50)	22 (73.33)	64 (45.07)	
Increase	0 (0.00)	1 (3.34)	1 (0.7)	

GGO, Ground-glass opacity;