JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Coronavirus Pandemic

Long-term follow-up of hospitalized COVID-19 patients with interstitial lung involvement

Özer Özdemir[1], Gülru Polat[1], Mine Gayaf[1], Filiz Güldaval[1], Damla Serçe Unat[1], Tarık Şimşek[1]

[1] Department of Chest Diseases, University of Health Sciences, Dr Suat Seren Chest Diseases and Surgery Training and Research Hospital, Izmir, Turkiye

Abstract

Introduction: Data regarding the residual lung findings persisting beyond 12 months from acute infection in patients with COVID-19 with pulmonary involvement are scarce. This study investigates the long-term radiological and functional findings of previously hospitalized COVID-19 patients who had residual pulmonary involvement at 3–6-month follow-up.

Methodology: This retrospective cohort study was an extended analysis of a previously published study, including patients with COVID-19 pneumonia hospitalized between June 2020 and March 2021. Residual lung involvement due to COVID-19 pneumonia was classified according to the presence of ground glass opacities, honeycombing, traction bronchiectasis, reticulations, and parenchymal bands.

Results: 51 out of the 157 patients with abnormal chest findings in high-resolution computed tomography (HRCT) scans at 3–6-month follow-up were included. Mean age of the study population was 60.5 ± 10.5 years; 35 subjects were male (68.6%). HRCT controls were obtained 25.7 ± 6.36 months after the diagnosis. There was regression of predefined radiological involvement in 39 patients (76.5%), whereas 11 patients (21.6%) exhibited stable findings, and one patient had progressive lung involvement with a usual interstitial pneumonia pattern. Persistent residual parenchymal bands were found mostly in ICU-admitted patients ($p = 0.04$), and reticulations were seen in patients with a CT severity score > 18 ($p = 0.04$).

Conclusions: In most patients with pulmonary sequelae, lesions showed improvement after 18 months, with complete resolution in about one third of patients after a 6-month follow-up. There was a correlation between initial severity and persistence of lung abnormalities.

Key words: COVID-19; residual interstitial findings; interstitial lung disease.

J Infect Dev Ctries 2026; 20(3):342-349. doi:10.3855/jidc.21215

(Received 17 December 2024 – Accepted 11 July 2025)

Introduction

The world has experienced a devastating pandemic of COVID-19, predominantly affecting the lungs and causing deaths mainly because of acute respiratory distress syndrome (ARDS) and cytokine storm. Besides its risk of mortality, disease may exhibit long-term or extended symptoms, namely "post-acute sequelae of SARS-CoV-2" (PASC) or "long COVID", and residual pulmonary parenchymal involvement with deteriorated lung function and exercise capacity [1-4]. During the pandemic era, numerous studies investigated the risk and type of interstitial pulmonary involvement seen in COVID-19 survivors, especially focusing on fibrotic sequelae [5-7].

A previous study conducted by our group observed residual parenchymal abnormalities -mostly reticulations and parenchymal bands- in 33.6% of previously hospitalized COVID-19 patients [5]. In the study by Stewart *et al.* evaluating over 3000 patients, up to 11% patients presented significant (> 10%) residual lung abnormalities, within the first 8 months following hospital discharge, with increasing risk in patients with low diffusion capacity, abnormal chest X-ray, and severe disease [8]. A recent meta-analysis showed 29% fibrotic changes in lungs at a median follow-up time of 3 months [9].

Growing evidence indicates residual lung involvement in the first year post-acute COVID-19, mainly including ground-glass opacities and fibrosis-like changes, in about one-third of the patients [10]. A persistent decline in pulmonary function tests and diffusion capacity has been observed in a subset of patients by the end of the first year [11].

However, it remains to be clarified whether these residual findings persist beyond 12 months and whether post-COVID patients exhibit a deteriorated lung function over longer follow-up periods. In a previous study conducted by our group, residual parenchymal involvement was identified in one-third of the study population, at 3-6 months after acute infection; also, the risk of parenchymal involvement positively correlated with more severe disease, especially in older male patients [5]. Among 646 screened patients, 150 patients were found to have residual parenchymal sequelae. As an extension of the previously reported study, this study aimed to investigate the evolution of pulmonary abnormalities in this cohort of unvaccinated patients

after 18 months from the initial diagnosis of COVID-19.

Methodology

This retrospective cohort study was planned as an extended analysis of a previously published study, including 446 out of 646 screened COVID-19 pneumonia patients who were hospitalized between June 2020 and March 2021 in a tertiary-level referral hospital of respiratory diseases in İzmir, Turkey. Initially, it was aimed to investigate the factors associated with the development of fibrosis-like lung involvement in 3-6 months follow-up visits of a cohort of hospitalized COVID-19 patients by using high-resolution computed tomography (HRCT) scan [5]. None of the patients were vaccinated against SARS-CoV-2. Local ethical committee board approval was obtained (16/08/2022; approval number: 2022/45-53).

Patients with residual lung involvement on 3–6-month HRCT scans after COVID-19 pneumonia were screened. Those with HRCT follow-up beyond 12 months after hospitalization were included in the study. Clinical and laboratory characteristics of the study population were obtained from hospital records. Laboratory data at the time of diagnosis were noted. Needs for supplemental oxygen treatment and intensive care unit care were also noted. Patients under 18 years of age and patients with a previous history of interstitial lung disease were excluded.

Pulmonary function test results of the patients were retrieved from hospital records, which were conducted by a 5-year experienced respiratory technician. Spirometry was conducted according to the European Thoracic Society/ American Thoracic Society (ETS/ATS) criteria [12].

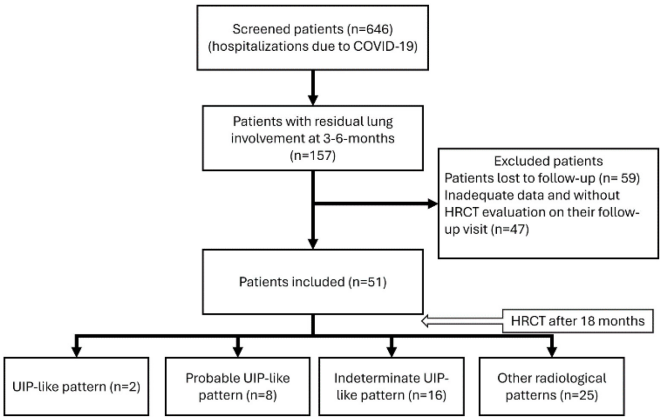
HRCT scans were achieved by following the high-resolution lung tomography protocol with scanning parameters of tube voltage 120 kVp, automatic tube current modulation, tube current 100–250 mAs, pitch 1.0–1.2 mm, with a slice thickness of 0.625 mm. The Supria True 64 CT Device (Fujifilm Healthcare Americas, Lexington, Massachusetts) was used. Computed tomography severity scores (CTSS) for study participants were calculated according to their lung involvement at the time of diagnosis [13]. The sum of the extent of lobar involvements revealed total severity scores. Scores for corresponding percentages of involvement are: 0 for 0%, 1 for < 5%, 2 for 5-25%, 3 for 26-49%, 4 for 50-75% and 5 for > 75%.

Residual lung involvement due to COVID-19 pneumonia was classified according to the presence of ground-glass opacities (GGO), honeycombing, traction bronchiectasis, reticulations, and parenchymal bands. A usual interstitial pneumonia (UIP)-like pattern was defined by the presence of honeycombing predominantly affecting the lower subpleural lung zones. A probable-UIP-like pattern was defined as the presence of traction bronchiectasis and reticulations predominantly in the lower lung fields. An indeterminate UIP-like pattern was defined as the absence of honeycombing and traction bronchiectasis, and the presence of interlobular septal thickenings and reticulations predominantly in the lower lobes.

HRCT scans obtained beyond 12 months were compared with those from the 3–6-month follow-up visits. According to the temporal changes in the extent of lung involvement, patients were classified as disease progression, disease regression, or stable disease. An experienced thoracic radiologist accomplished the evaluation of HRCT scans. Comparison of long-term residual findings was achieved between groups according to the need for ICU transfer during the hospitalization period, and also according to lung involvement severity, which was evaluated by CTSS. HRCT controls were obtained 25.7 ± 6.36 months after diagnosis.

Statistical analysis was performed using IBM SPSS V22 (Statistical package for the Social Sciences, IBM, Armonk, New York). Data were presented as mean ± standard deviation for variables with normal distribution and median (interquartile range) for non-normally distributed variables. The chi-square test was used to compare categorical variables. The Student *t*-test or Mann-Whitney U test was applied to compare continuous variables, according to data distribution. A $p < 0.05$ was considered statistically significant.

Figure 1. Flow diagram of the study population.



Results

There were 157 patients out of the pre-screened

cohort of 646 hospitalized COVID-19 subjects who had residual parenchymal findings on high-resolution computed tomography (HRCT) scans at their 3–6-month follow-up. From this patient cohort, 51 patients were included in the study because of the availability of control HRCT after 18 months from the initial COVID-19 diagnosis. Patients without an HRCT evaluation on follow-up (n = 37) and patients whose HRCT images were unavailable for evaluation (n = 10) were excluded. The study flowchart is presented in Figure 1.

Basal characteristics of the patient population are presented in Table 1. The mean age of the study population was 60.5 ± 10.5 years; 35 patients were male (68.6%). Bilateral lung involvement was present at the time of diagnosis in 98% of the patients. Mean CTSS was 12.6 ± 5.7, and 21.6% of the patients needed intensive care unit (ICU) transfer during the management period. None of the patients were vaccinated against SARS-CoV-2.

HRCT controls were obtained 25.7 ± 6.36 months after diagnosis. A comparison of the radiological findings at 3-6 months and long-term follow-up CT of the patients is seen in Table 2. Complete resolution of radiological abnormalities was observed in 17 patients (33%), regression in 39 patients (76.5%), and stable long-term imaging findings in 11 patients (21.6%). In one patient, progression of fibrotic lesions was observed, and the patient was started on anti-fibrotic therapy with the diagnosis of progressive pulmonary fibrosis. This patient was a 57-year-old male with a history of 20 pack-years of smoking. He did not have any comorbidities. He had bilateral diffuse involvement of COVID-19 pneumonia with a CTSS of 12 at the time of diagnosis. Patients with regressive HRCT findings

Table 1. Demographic and clinical characteristics of the study population at the time of diagnosis of COVID-19 pneumonia.

Characteristics	Total population (n = 51)
Age, years, mean ± SD	60.5 ± 10.5
Sex, male, n (%)	35 (68.6)
Smoking, n (%)	13 (25.5)
Comorbidity, n (%)	32 (62.7)
Hypertension, n (%)	22 (43.1)
Diabetes Mellitus, n (%)	10 (19.6)
Cardiovascular disease, n (%)	8 (15.7)
Heart failure, n (%)	2 (3.9)
COPD, n (%)	5 (9.8)
SARS-CoV-2 PCR Positivity, n (%)	40 (78,4)
Typical HRCT characteristics, n (%)	51 (100)
Bilateral lung involvement, n (%)	50 (98)
CT Severity Scores, n, mean ± SD	12.6 ± 5.7
CT Severity Score ≥ 18, n (%)	11 (21.6)
Laboratory characteristics	
Hemoglobin, gr/dL	13.0 ± 1.80
Leucocytes, /mm^3	7950 (4400)
Neutrophils, /mm^3	6300 (4525)
Monocytes, /mm^3	500 (400)
Lymphocytes, /mm^3	850 (1075)
Platelets, /mm^3	263500 (149750)
CRP, mg/dL	80.5 (90.1)
Ferritin, ng/mL	471.4 (653.1)
D-dimer, ng/mL	783.5 (1449)
Albumin, g/L	3.31 (0.78)
LDH, U/L	281.5 (257.5)
Glucose, mg/dL	128.5 (50)
Corticosteroid treatment, n	37 (72.5)
Duration of corticosteroid treatment, days	7.5 ± 4.19
Pulse corticosteroid treatment, n	5 (9.8)
ICU need, n	11 (21.6)
Oxygen support on admission, n	32 (62.7)
Long-term oxygen support, n	8 (15.7)
Rehospitalization after COVID-19	8 (15.7)

Data are presented as median (interquartile range) if otherwise is not stated. SD: standard deviation; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus–2; PCR: Polymerase Chain Reaction; HRCT: High Resolution Computed Tomography; CRP: C- Reactive Protein; LDH: Lactate Dehydrogenase; ICU: Intensive Care Unit.

Table 2. Distribution of lung parenchymal abnormalities in patients evaluated by HRCT scan of lungs on their follow-up visit.

	HRCT findings (n = 51)	
	First follow-up HRCT (between 3-6 months)	Second follow-up HRCT (Long-term) *
Normal HRCT	0	17 (33.3)
Parenchymal bands, n (%)	28 (54.9)	18 (35.3)
Reticulations, n (%)	31 (60.8)	22 (43.1)
Ground-glass opacities, n (%)	25 (49)	18 (35.3)
Traction bronchiectasis, n (%)	19 (37.3)	15 (29.4)
Interlobular septal thickenings, n (%)	10 (19.6)	4 (7.8)
Honeycombing, n (%)	2 (3.9)	2 (3.9)
UIP-like	2 (3.9)	2 (3.9)
Probable UIP-like	12 (23.5)	8 (15.7)
Indeterminate UIP-like	20 (39.2)	16 (31.4)
Only parenchymal bands	6 (11.8)	6 (11.8)
GGO with parenchymal bands	5 (9.8)	2 (3.9)
Traction bronchiectasis without reticulations	5 (9.8)	3 (5.9)
Pure GGO	1 (2)	2 (3.9)
Diffuse reticulations	0	2 (3.9)
Upper lobe traction bronchiectasis with reticulations	6 (11.8)	4 (7.8)
Only interlobular septal thickenings	1 (2)	0

* Long-term follow-up HRCT were performed after 18 months; HRCT: high resolution computed tomography; UIP: Usual Interstitial Pneumonia; GGO: Ground-Glass Opacities.

did not differ from patient with HRCT findings in terms of baseline biomarkers like C-reactive protein (CRP), ferritin, D-dimer or albumin (respectively, median 64.7 mg/dL (IQR: 83.5) vs. 96.6 mg/dL (IQR: 115.4), p = 0.79; median 518.3 ng/mL (IQR: 720.3 ng/mL) vs. 378.5 ng/mL (IQR: 650.7), p = 0.63; 801.5 ng/mL (IQR: 1449) vs. 1509.5 ng/mL (IQR: 2085 ng/mL), p = 0.74 and median 3.29 mg/dL (IQR: 0.6) vs. 3.81 mg/dL (IQR:0.9), p=0.10) nor sex or presence of comorbidities (respectively, p = 1.00 and p = 1.00).

Ground-glass opacities, parenchymal bands, reticulations, and interlobular septal thickenings were less frequently observed in long-term HRCT controls. However, 4 patients who were previously noted to have traction bronchiectasis presented a resolution of the bronchiectasis on follow-up HRCT scans. Honeycombing was observed in 2 patients; one patient previously considered having honeycombing revealed findings compatible with para-septal emphysema with reticulations, which were improved in control HRCT.

Radiological patterns other than the UIP-like pattern, which include honeycombing, were found to be observed less often in long-term HRCT scans. The most prominent differences were a decrease in the presence of interlobular septal thickenings from 19.6% to 7.8% of subjects and parenchymal bands from 54% to 35.3% of subjects. Pure GGOs and diffuse reticulations were more frequently seen in control HRCT scans; this was because of regression of co-occurrent parenchymal findings.

Pulmonary function tests were obtained in 47 patients, and median forced vital capacity (FVC) of the study population was 2360 mL (Interquartile range (IQR): 1173 mL), 90% (IQR: 25%); and median diffusion capacity of lung for carbon monoxide (DL_{CO}) was 6.47 mL/mmHg/dk (IQR: 4.01 mL/mmHg/min). Impairment in FVC levels was present in 15 patients (29.4%), whereas impairment of diffusion capacity was detected in 21 patients (41.2%) at 18 months. Severe impairment of diffusion capacity (DL_{CO} < 40%) was detected in 2 patients (3.9%), and severe FVC impairment (< 50%) was found in only 1 patient at the end of 18 months. One patient with DL_{CO} < 40% was a 71-year-old non-smoker female with hypertension, with a CTSS of 6 at the time of diagnosis. She had a history of hospitalization due to pneumonia one year after COVID-19 pneumonia. The other patient was a 53-year-old ex-smoker male. Although he did not need ICU care during management, he was given steroid therapy and discharged on long-term oxygen therapy after COVID-19 pneumonia. The patient with severe FVC impairment was a 69-year-old male with a history of 50 pack-years of smoking and hypertension, chronic obstructive pulmonary disease, and cardiovascular disease. He needed ICU care for 9 days for the management of COVID-19 pneumonia and was treated with steroids and tocilizumab. He was also discharged onto long-term oxygen therapy.

Comparison of pulmonary function tests between patients with normal HRCT findings (n = 17) and patients with residual lung involvement (n = 34) did not reveal any significant difference of FEV_1, FVC or DL_{CO} levels (respectively, 2770 ± 1114.2 mL vs. 2552 ± 885.8 mL, p = 0.46; 3424 ± 1188.3 mL vs. 3202 ± 1014.2 mL, p = 0.50; 7.14 ± 2.87 mL/mmHg/min vs. 6.63 ± 2.2 mL/mmHg/min, p = 0.50). However, patients with normal HRCT findings at 18 months tend to have FVC levels over 80% and the difference is at the edge of significance (p = 0.06); although there is no significant difference in DL_{CO} levels between patients with

Table 3. Radiological findings and pulmonary function test impairments according to the need for ICU and basal extent of lung involvement.

	ICU (n = 11)	Non-ICU (n = 40)	*p*	CTSS > 18 (n = 11)	CTSS < 18 (n = 40)	*p*
HRCT findings						
Progression, n (%)	0	1 (2.5)	-	0	1 (2.5)	-
Regression, n (%)	8 (72.7)	31 (77.5)	0.77	9 (81.8)	30 (75)	0.82
Normal HRCT*	1 (9.1)	16 (40)	0.08	1 (9.1)	16 (40)	0.08
UIP-like pattern	0	2 (5)	1.0	0	2 (5)	1.0
Probable-UIP like pattern	2 (18.2)	4 (10)	0.6	4 (36.4)	2 (5)	0.02
Indeterminate UIP pattern	2 (18.2)	6 (15)	1.0	3 (27.3)	5 (12.5)	0.35
Parenchymal bands, n (%)	7 (63.6)	11 (27.5)	0.04	5 (45.5)	13 (32.5)	0.49
Reticulations, n (%)	6 (54.5)	16 (40)	0.50	8 (72.7)	14 (35)	0.04
Ground glass opacities, n (%)	5 (45.5)	13 (32.5)	0.49	6 (54.5)	12 (30)	0.16
Traction bronchiectasis, n (%)	5 (45.5)	10 (25)	0.26	4 (36.4)	11 (27.5)	0.71
Interlobular septal thickenings, n (%)	1 (9.1)	3 (7.5)	0.86	1 (9.1)	3 (7.5)	1.0
Honeycombing, n (%)	0	2 (5)	1.0	0	2 (5)	1.0
Pulmonary function tests						
DL_{CO} impairment (below 80%), n (%)	4 (36.4)	17 (47.2)	0.73	7 (70)	14 (37.8)	0.09
FVC impairment (below 80%), n (%)	4 (36.4)	11 (28.9)	0.72	3 (27.3)	12 (31.6)	1.00

HRCT: high-resolution computed tomography; UIP: Usual Interstitial Pneumonia; CTSS: computed tomography severity score; DLCO: diffusion capacity of lungs for carbon monoxide; FVC: forced vital capacity.

improved HRCT findings and patients with worsened or stable HRCT findings ($p = 1.00$).

A comparison of radiological and spirometric characteristics of the study population according to the need for ICU transfer during their management for COVID-19 and CTSS level at the time of diagnosis is presented in Table 3. Parenchymal bands mostly remained in long-term HRCT of ICU-admitted patients ($p = 0.04$), and reticulations were mostly seen in patients with CTSS > 18 ($p = 0.04$). Non-ICU subjects and patients with CTSS lower than 18 showed more complete resolution of HRCT findings, although not significantly ($p = 0.08$).

Rehospitalization after COVID-19 pneumonia was required for 8 patients, none of whom were rehospitalized because of a recurrence of COVID-19. The reasons for hospitalizations were a new diagnosis of cancer in one patient, pulmonary thromboembolism in one patient, hypoxemic respiratory failure because of cardiovascular disease in 2 patients, pneumothorax in one patient, and respiratory infections other than COVID-19 in 3 patients. None of the study population experienced a recurrence of COVID-19.

Discussion

In this study, a substantial portion of hospitalized COVID-19 patients with parenchymal lung abnormalities at 3–6-month follow-up HRCT scans demonstrated regression of these abnormalities, accompanied by normal spirometric values at their long-term follow-up. Only one patient developed progressive pulmonary involvement and required anti-fibrotic therapy, whereas one in five patients had residual but stable parenchymal lung abnormalities. Notably, about one-third of those with residual HRCT abnormalities at 3-6 months showed complete resolution after 18 months.

Growing evidence has documented residual pulmonary abnormalities after COVID-19 pneumonia, particularly beyond 12 months of follow-up [14-18]. A recent meta-analysis revealed a pooled estimated prevalence of 43.5% for residual lung abnormalities at 12 months in COVID-19 pneumonia patients [3]. Reported prevalence rates of traction bronchiectasis ranged from 1.6 to 25.7%; while honeycombing prevalence was unremarkable (0% - 1.1%; I 2 = 58%; 95% PI: 0-60). In the study of Luger *et al*., prospective evaluation of COVID-19 patients at intervals up to 12 months revealed a gradual improvement of lung involvement, with abnormalities persisting in 54% of the study population at 12 months [19]. These results align with the present findings; however, heterogeneity in study populations, disease severity, and assessment time points should be noted.

Gonzales *et al.* explored residual abnormalities in pulmonary function tests and CT scans of COVID-19 patients in a 2-year follow-up time [20]. However, their study population consisted only of ICU survivors. They found diffusion abnormalities in 46% of patients at their 24-month evaluation; more than half of the patients retained HRCT abnormalities, with 14.5% bearing fibrotic changes. Although pulmonary function tests and exercise capacity were stable between 12 and 24 months, CTSS and quality of life measures continued to improve in the second year. In contrast, Wu *et al.* failed to show improvement in HRCT residual findings in 12 months compared with the findings in 9 months [17].

The most common pulmonary function abnormality in previous studies is impairment of diffusion capacity. The meta-analysis by Lee *et al.* showed a pooled prevalence of 35% for impaired diffusion capacity, whereas impairment of FVC had a pooled prevalence of 8% [21]. In the present cohort, 41.2% had impaired DL_{CO} at the end of 18 months, and 29.4% had impaired FVC; mostly of mild-to-moderate severity. In a previous study, at the end of one year, one fourth of patients had pulmonary function test impairment, which was more prominent following severe and critical disease [11]. In the present cohort, there was no difference in pulmonary function test impairment between ICU and non-ICU patients, nor between those with severe versus non-severe baseline radiological involvement.

In the present study, 29.4% of the patients had fibrotic sequelae in the lungs, either as traction bronchiectasis or honeycombing or both, at long-term follow-up. Interestingly, about 8% of patients with traction bronchiectasis at 3-6 months demonstrated resolution over two years. In one patient, apparent honeycombing was later reinterpreted as reticulations with para-septal emphysema. Traction bronchiectasis and honeycombing are regarded as established fibrotic lung lesions [22]. Prior SARS follow-up studies documented resolution of similar reversible bronchial dilations initially described as traction bronchiectasis at 84 months compared with 6-month HRCT scans [23]. Similar reversibility has also been reported in COVID-19 patients [24]. These findings suggest that some early bronchial changes represent pseudo-bronchiectasis or bronchial distortion, rather than irreversible traction bronchiectasis [25].

One patient experienced progression of fibrotic involvement at 24 months, with honeycombing developing in addition to prior traction bronchiectasis.

This patient, a 57-year-old male smoker without comorbidities or any use of medication, exhibited symptomatic worsening and a decline in diffusion capacity necessitating anti-fibrotic therapy. Whether COVID-19 infection served as a trigger for progressive fibrosis remains uncertain. However, he did not have any systemic or pulmonary disease before COVID-19 pneumonia. The association of COVID-19 with progressive fibrosis of the lungs remains unknown. In a prospective study by Soliman *et al*., patients with fibrotic post-COVID lesions detected after 4 months from acute disease were followed up for 16 months, and in most patients these lesions remained stable [26]. In this patient, anti-fibrotic therapy was indicated due to the progression of pulmonary findings. In a case series of COVID-19 patients who have over 5% fibrotic involvement in their HRCT scans, anti-fibrotic therapy seems to exert positive effects on pulmonary functions and lung findings [7,27]. However, such evidence is limited by a small sample size and a lack of a control group. The optimal timing for initiation of anti-fibrotic therapy in this context remains unclear.

To date, there is limited evidence regarding the pulmonary parenchymal involvement of COVID-19 patients beyond 12 months. However, several limitations should be acknowledged: the retrospective, single-center design; absence of a healthy control group similar to previous COVID-19 studies; lack of baseline pulmonary function test data prior to infection; variable follow-up duration (18-32 months); and reliance on clinical and radiological findings without a clear laboratory confirmation in 22% for the diagnosis of COVID-19. Rapid antigen tests were not available at the time of the study. However, the epidemiological situation at that time showed a burst in cases, and clinical and radiological properties of the subjects were compatible with COVID-19 pneumonia. The study involves patients with the original SARS-CoV-2 strain. These findings may not be generalizable to Delta, Omicron, or other variants.

In conclusion, most patients with post-COVID-19 pulmonary sequelae demonstrated improvement after 18 months, and an additional complete resolution was evident in about one-third of patients after 6 months. Also, with the results of the present study and data from the literature, it is still hard to determine an optimal timing for HRCT and pulmonary function tests, but some patients may experience further improvement of HRCT findings and pulmonary functions beyond 12 months from acute COVID-19. Evidence for the progression of remaining fibrotic lesions is insufficient; however, patients should undergo continued symptomatic and functional monitoring. Clinicians should consider anti-fibrotic therapy for patients with progressive fibrosis. Prospective, larger studies with longer follow-up are essential to elucidate the natural history and evolution of COVID-19 sequelae on the pulmonary parenchyma beyond 18 months from the acute phase of the disease.

Corresponding author

Dr. Özer Özdemir
Associate Professor
Department of Chest Diseases, University of Health Sciences,
Dr Suat Seren Chest Diseases and Surgery Training and Research Hospital, Izmir, Turkiye.
Tel: +90 (232) 433 33 33
Fax: + 90 (232) 458 72 62
Email: ozer_ozdemir@yahoo.com

Conflict of interest

No conflict of interest is declared.

References

1. Thaweethai T, Jolley SE, Karlson EW, Levitan EB, Levy B, McComsey GA, McCorkell L, Nadkarni GN, Parthasarathy S, Singh U, Walker TA, Selvaggi CA, Shinnick DJ, Schulte CCM, Atchley-Challenner R, Alba GA, Alicic R, Altman N, Anglin K, Argueta U, Ashktorab H, Baslet G, Bassett IV, Bateman L, Bedi B, Bhattacharyya S, Bind MA, Blomkalns AL, Bonilla H, Bush PA, Castro M, Chan J, Charney AW, Chen P, Chibnik LB, Chu HY, Clifton RG, Costantine MM, Cribbs SK, Davila Nieves SI, Deeks SG, Duven A, Emery IF, Erdmann N, Erlandson KM, Ernst KC, Farah-Abraham R, Farner CE, Feuerriegel EM, Fleurimont J, Fonseca V, Franko N, Gainer V, Gander JC, Gardner EM, Geng LN, Gibson KS, Go M, Goldman JD, Grebe H, Greenway FL, Habli M, Hafner J, Han JE, Hanson KA, Heath J, Hernandez C, Hess R, Hodder SL, Hoffman MK, Hoover SE, Huang B, Hughes BL, Jagannathan P, John J, Jordan MR, Katz SD, Kaufman ES, Kelly JD, Kelly SW, Kemp MM, Kirwan JP, Klein JD, Knox KS, Krishnan JA, Kumar A, Laiyemo AO, Lambert AA, Lanca M, Lee-Iannotti JK, Logarbo BP, Longo MT, Luciano CA, Lutrick K, Maley JH, Marathe JG, Marconi V, Marshall GD, Martin CF, Matusov Y, Mehari A, Mendez-Figueroa H, Mermelstein R, Metz TD, Morse R, Mosier J, Mouchati C, Mullington J, Murphy SN, Neuman RB, Nikolich JZ, Ofotokun I, Ojemakinde E, Palatnik A, Palomares K, Parimon T, Parry S, Patterson JE, Patterson TF, Patzer RE, Peluso MJ, Pemu P, Pettker CM, Plunkett BA, Pogreba-Brown K, Poppas A, Quigley JG, Reddy U, Reece R, Reeder H, Reeves WB, Reiman EM, Rischard F, Rosand J, Rouse DJ, Ruff A, Saade G, Sandoval GJ, Schlater SM, Shepherd F, Sherif ZA, Simhan H, Singer NG, Skupski DW, Sowles A, Sparks JA, Sukhera FI, Taylor BS, Teunis L, Thomas RJ, Thorp JM, Thuluvath P, Ticotsky A, Tita AT, Tuttle KR, Urdaneta AE, Valdivieso D, VanWagoner TM, Vasey A, Verduzco-Gutierrez M, Wallace ZS, Ward HD, Warren DE, Weiner SJ, Welch S, Whiteheart SW, Wiley Z, Wisnivesky JP, Yee LM, Zisis S, Horwitz LI and Foulkes AS (2023) Development of a definition of postacute sequelae of SARS-CoV-2 infection. Jama 329: 1934-46. doi: 10.1001/jama.2023.8823.

2. Baroni C, Potito J, Perticone ME, Orausclio P, and Luna CM (2023) How does long-COVID impact prognosis and the long-term sequelae? Viruses 15: 1173. doi: 10.3390/v15051173.
3. Bocchino M, Rea G, Capitelli L, Lieto R and Bruzzese D (2023) Chest CT lung abnormalities 1 year after COVID-19: A systematic review and meta-analysis. Radiology 308: e230535. doi: 10.1148/radiol.230535.
4. Hadak A, Premec D, Perkovic M, Dolenec V, Bozan M, Nedeljkovic V, Kelava T and Markovic I (2024) Serum tryptase levels in patients with post-acute COVID-19 syndrome. Bratisl Lek Listy 125: 318-21. doi: 10.4149/bll_2024_47.
5. Polat G, Ozdemir O, Ermin S, Unat DS, Sahin GV, Turk MA, Guldaval F, Susam S and Kirakli C (2022) Factors affecting the risk of interstitial lung disease development in hospitalized patients with COVID-19 pneumonia. Respir Care 67: 1272-81. doi: 10.4187/respcare.09816.
6. Besutti G, Monelli F, Schiro S, Milone F, Ottone M, Spaggiari L, Facciolongo N, Salvarani C, Croci S, Pattacini P and Sverzellati N (2022) Follow-up CT patterns of residual lung abnormalities in severe COVID-19 pneumonia survivors: a multicenter retrospective study. Tomography 8: 1184-95. doi: 10.3390/tomography8030097.
7. Kerget B, Cil G, Araz O, Alper F and Akgun M (2022) When and how important is anti-fibrotic therapy in the post-COVID-19 period? Bratisl Lek Listy 123: 653-6958. doi: 10.4149/bll_2022_105.
8. Stewart I, Jacob J, George PM, Molyneaux PL, Porter JC, Allen RJ, Aslani S, Baillie JK, Barratt SL, Beirne P, Bianchi SM, Blaikley JF, Chalmers JD, Chambers RC, Chadhuri N, Coleman C, Collier G, Denneny EK, Docherty A, Elneima O, Evans RA, Fabbri L, Gibbons MA, Gleeson FV, Gooptu B, Greening NJ, Guio BG, Hall IP, Hanley NA, Harris V, Harrison EM, Heightman M, Hillman TE, Horsley A, Houchen-Wolloff L, Jarrold I, Johnson SR, Jones MG, Khan F, Lawson R, Leavy O, Lone N, Marks M, McAuley H, Mehta P, Parekh D, Hanley KP, Plate M, Pearl J, Poinasamy K, Quint JK, Raman B, Richardson M, Rivera-Ortega P, Saunders L, Saunders R, Semple MG, Sereno M, Shikotra A, Simpson AJ, Singapuri A, Smith DJF, Spears M, Spencer LG, Stanel S, Thickett DR, Thompson AAR, Thorpe M, Walsh SLF, Walker S, Weatherley ND, Weeks ME, Wild JM, Wootton DG, Brightling CE, Ho LP, Wain LV and Jenkins GR (2023) Residual lung abnormalities after COVID-19 hospitalization: Interim analysis of the UKILD post-COVID-19 study. Am J Respir Crit Care Med 207: 693-703. doi: 10.1164/rccm.202203-0564OC.
9. Fabbri L, Moss S, Khan FA, Chi W, Xia J, Robinson K, Smyth AR, Jenkins G and Stewart I (2023) Parenchymal lung abnormalities following hospitalisation for COVID-19 and viral pneumonitis: a systematic review and meta-analysis. Thorax 78: 191-201. doi: 10.1136/thoraxjnl-2021-218275.
10. Watanabe A, So M, Iwagami M, Fukunaga K, Takagi H, Kabata H and Kuno T (2022) One-year follow-up CT findings in COVID-19 patients: A systematic review and meta-analysis. Respirology 27: 605-16. doi: 10.1111/resp.14311.
11. van Willigen HDG, Wynberg E, Verveen A, Dijkstra M, Verkaik BJ, Figaroa OJA, de Jong MC, van der Veen A, Makowska A, Koedoot N, Nieuwkerk PT, Boyd A, Prins M, de Jong MD, de Bree GJ, van den Aardweg JG and Group RES (2023) One-fourth of COVID-19 patients have an impaired pulmonary function after 12 months of disease onset. PLoS One 18: e0290893. doi: 10.1371/journal.pone.0290893.
12. Wanger J, Clausen JL, Coates A, Pedersen OF, Brusasco V, Burgos F, Casaburi R, Crapo R, Enright P, van der Grinten CP, Gustafsson P, Hankinson J, Jensen R, Johnson D, Macintyre N, McKay R, Miller MR, Navajas D, Pellegrino R and Viegi G (2005) Standardisation of the measurement of lung volumes. Eur Respir J 26: 511-22. doi: 10.1183/09031936.05.00035005.
13. Li K, Wu J, Wu F, Guo D, Chen L, Fang Z and Li C (2020) The clinical and chest CT features associated with severe and critical COVID-19 pneumonia. Invest Radiol 55: 327-31. doi: 10.1097/rli.0000000000000672.
14. Vargas Centanaro G, Calle Rubio M, Alvarez-Sala Walther JL, Martinez-Sagasti F, Albuja Hidalgo A, Herranz Hernandez R and Rodriguez Hermosa JL (2022) Long-term outcomes and recovery of patients who survived COVID-19: LUNG INJURY COVID-19 Study. Open Forum Infect Dis 9: ofac098. doi: 10.1093/ofid/ofac098.
15. Faverio P, Luppi F, Rebora P, D'Andrea G, Stainer A, Busnelli S, Catalano M, Modafferi G, Franco G, Monzani A, Galimberti S, Scarpazza P, Oggionni E, Betti M, Oggionni T, De Giacomi F, Bini F, Bodini BD, Parati M, Bilucaglia L, Ceruti P, Modina D, Harari S, Caminati A, Intotero M, Sergio P, Monzillo G, Leati G, Borghesi A, Zompatori M, Corso R, Valsecchi MG, Bellani G, Foti G and Pesci A (2022) One-year pulmonary impairment after severe COVID-19: a prospective, multicenter follow-up study. Respir Res 23: 65. doi: 10.1186/s12931-022-01994-y.
16. Tarraso J, Safont B, Carbonell-Asins JA, Fernandez-Fabrellas E, Sancho-Chust JN, Naval E, Amat B, Herrera S, Ros JA, Soler-Cataluna JJ, Rodriguez-Portal JA, Andreu AL, Marin M, Rodriguez-Hermosa JL, Gonzalez-Villaescusa C, Soriano JB, Signes-Costa J and team C-Fs (2022) Lung function and radiological findings 1 year after COVID-19: a prospective follow-up. Respir Res 23: 242. doi: 10.1186/s12931-022-02166-8.
17. Wu X, Liu X, Zhou Y, Yu H, Li R, Zhan Q, Ni F, Fang S, Lu Y, Ding X, Liu H, Ewing RM, Jones MG, Hu Y, Nie H and Wang Y (2021) 3-month, 6-month, 9-month, and 12-month respiratory outcomes in patients following COVID-19-related hospitalisation: a prospective study. Lancet Respir Med 9: 747-54. doi: 10.1016/S2213-2600(21)00174-0.
18. Huang L, Yao Q, Gu X, Wang Q, Ren L, Wang Y, Hu P, Guo L, Liu M, Xu J, Zhang X, Qu Y, Fan Y, Li X, Li C, Yu T, Xia J, Wei M, Chen L, Li Y, Xiao F, Liu D, Wang J, Wang X and Cao B (2021) 1-year outcomes in hospital survivors with COVID-19: a longitudinal cohort study. Lancet 398: 747-58. doi: 10.1016/S0140-6736(21)01755-4.
19. Luger AK, Sonnweber T, Gruber L, Schwabl C, Cima K, Tymoszuk P, Gerstner AK, Pizzini A, Sahanic S, Boehm A, Coen M, Strolz CJ, Woll E, Weiss G, Kirchmair R, Feuchtner GM, Prosch H, Tancevski I, Loffler-Ragg J and Widmann G (2022) Chest CT of lung injury 1 year after COVID-19 pneumonia: The CovILD Study. Radiology 304: 462-70. doi: 10.1148/radiol.211670.
20. Gonzalez J, Zuil M, Benitez ID, de Batlle J, Aguila M, Santisteve S, Varvara N, Monge A, Forns N, Vaca R, Minguez O, Seck F, Gort-Paniello C, Moncusi-Moix A, Caballero J, Barbera C, de Gonzalo-Calvo D, Torres A, Barbe F and Project C (2023) Long-term outcomes in critical COVID-19 survivors: a 2-year longitudinal cohort. Arch Bronconeumol 59: 691-97. doi: 10.1016/j.arbres.2023.08.006.
21. Lee JH, Yim JJ and Park J (2022) Pulmonary function and chest computed tomography abnormalities 6-12 months after recovery from COVID-19: a systematic review and meta-

analysis. Respir Res 23: 233. doi: 10.1186/s12931-022-02163-x.
22. Hansell DM, Bankier AA, MacMahon H, McLoud TC, Müller NL and Remy J (2008) Fleischner Society: glossary of terms for thoracic imaging. Radiology 246: 697-722. doi: 10.1148/radiol.2462070712.
23. Wu X, Dong D and Ma D (2016) Thin-section computed tomography manifestations during convalescence and long-term follow-up of patients with severe acute respiratory syndrome (SARS). Med Sci Monit 22: 2793-9. doi: 10.12659/msm.896985.
24. Hu Q, Liu Y, Chen C, Sun Z, Wang Y, Xiang M, Guan H and Xia L (2021) Reversible bronchiectasis in COVID-19 survivors with acute respiratory distress syndrome: Pseudobronchiectasis. Front Med (Lausanne) 8: 739857. doi: 10.3389/fmed.2021.739857.
25. Martini K, Larici AR, Revel MP, Ghaye B, Sverzellati N, Parkar AP, Snoeckx A, Screaton N, Biederer J, Prosch H, Silva M, Brady A, Gleeson F, Frauenfelder T and European Society of Thoracic Imaging tESoR (2022) COVID-19 pneumonia imaging follow-up: when and how? A proposition from ESTI and ESR. Eur Radiol 32: 2639-49. doi: 10.1007/s00330-021-08317-7.
26. Soliman S, Soliman H, Creze M, Brillet PY, Montani D, Savale L, Jais X, Bulifon S, Jutant EM, Rius E, Devilder M, Beurnier A, Colle R, Gasnier M, Pham T, Morin L, Noel N, Lecoq AL, Becquemont L, Figueiredo S, Harrois A, Bellin MF, Monnet X, Meyrignac O and group Cs (2024) Radiological pulmonary sequelae after COVID-19 and correlation with clinical and functional pulmonary evaluation: results of a prospective cohort. Eur Radiol 34: 1037-52. doi: 10.1007/s00330-023-10044-0.
27. Kerget B, Cil G, Araz O, Alper F and Akgun M (2023) Comparison of two antifibrotic treatments for lung fibrosis in post-COVID-19 syndrome: A randomized, prospective study. Med Clin (Engl Ed) 160: 525-30. doi: 10.1016/j.medcle.2022.12.019.