

Pulmonary Function Impairment Following Moderate and Severe COVID-19 Pneumonia: A Prospective Study

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Abstract

Background: Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), primarily affects the respiratory system and may result in persistent pulmonary dysfunction even after clinical recovery. Post-COVID pulmonary sequelae such as restrictive ventilatory defects and impaired diffusion capacity have been reported in several follow-up studies. However, data on long-term pulmonary function recovery among patients with moderate and severe COVID-19 pneumonia remain limited in many regions. **Objective:** To evaluate pulmonary function outcomes in patients recovering from moderate and severe COVID-19 pneumonia and to determine the prevalence of spirometric abnormalities and diffusion impairment after recovery. **Methods:** This prospective observational study was conducted at Government Medical College (GMC) Anantnag. A total of 110 patients with laboratory-confirmed COVID-19 infection diagnosed by reverse transcriptase polymerase chain reaction (RT-PCR) or rapid antigen test were included. Patients were categorized as having moderate or severe disease according to national clinical management guidelines. Individuals with pre-existing chronic lung diseases such as chronic obstructive pulmonary disease or interstitial lung disease and those requiring mechanical ventilation were excluded. Pulmonary function tests were performed at least two months after hospitalization and included spirometry, lung volumes, and diffusion capacity for carbon monoxide (DLCO). Spirometry was interpreted according to standardized ERS guidelines. Patterns were categorized as normal, restrictive, obstructive, or mixed. DLCO values $\geq 80\%$ predicted were considered normal. **Results:** Among the 110 participants, 66 (60%) were males and 44 (40%) were females. The age of patients ranged from 21 to 94 years, with a mean age of 63.8 ± 14.5 years. Most patients (70%) belonged to the 50–80-year age group. Moderate disease was observed in 87 patients (79.1%), while 23 patients (20.9%) had severe disease. The most common comorbidity was hypertension (25.45%), followed by diabetes mellitus (19.1%). Severe disease was more frequently observed among patients with diabetes mellitus (61.9%). Active or past smoking history was present in 46 patients (41.8%). Pulmonary function tests demonstrated normal spirometry in 102 patients (92.7%). Restrictive ventilatory defect was observed in 6 patients (5.5%), while obstructive pattern was noted in 2 patients (1.8%). Among patients with moderate disease, 97.7% had normal spirometry, whereas 73.9% of patients with severe disease had normal pulmonary function results. Diffusion capacity impairment (DLCO $< 80\%$ predicted) was observed in 11 patients (10%), including 3 patients (3.5%) with moderate disease and 8 patients (34.8%) with severe disease. **Conclusion:** Most patients recovering from moderate COVID-19 pneumonia demonstrated normal pulmonary function during follow-up. However, individuals with severe disease showed a higher prevalence of restrictive ventilatory defects and impaired diffusion capacity. These findings suggest that disease severity is an important determinant of persistent pulmonary dysfunction after COVID-19 infection. Long-term respiratory follow-up and pulmonary rehabilitation may be beneficial, particularly for patients who experienced severe disease.

Keywords: COVID-19; pulmonary function test; spirometry; diffusion capacity; post-COVID lung function; SARS-CoV-2.



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INTRODUCTION

Coronavirus disease 2019 (COVID-19) is an infectious respiratory illness caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). First identified in Wuhan, China in late 2019, the infection rapidly spread across continents and was declared a global pandemic by the World Health Organization in March 2020. Since then, the disease has resulted in substantial morbidity and mortality worldwide. Although most infected individuals experience mild symptoms, a significant proportion develop moderate to severe respiratory illness requiring hospitalization.

The respiratory system represents the primary target of SARS-CoV-2 infection. Viral entry into host cells occurs through interaction with angiotensin-converting enzyme-2 receptors expressed on alveolar epithelial cells. The infection triggers an inflammatory cascade characterized by immune activation, cytokine release, and endothelial injury. In severe cases, the resulting inflammatory response leads to diffuse alveolar damage, disruption of the alveolar-capillary barrier, and formation of hyaline membranes within the lung parenchyma.

Pathological studies of lung tissue in patients with severe COVID-19 have demonstrated extensive alveolar epithelial destruction, vascular congestion, and microthrombi formation. These pathological changes may progress to fibroproliferative remodeling of the lung interstitium, resulting in persistent structural abnormalities even after resolution of the acute infection. Such alterations can impair gas exchange and lead to long-term respiratory dysfunction.

Recent studies have highlighted the growing concern regarding post-COVID pulmonary sequelae. Survivors of moderate and severe disease frequently report persistent symptoms such as dyspnea, fatigue, and exercise intolerance months after recovery. Pulmonary function testing has emerged as an important tool for evaluating these long-term consequences. Abnormalities in diffusion capacity, lung volumes, and spirometric parameters have been reported in several follow-up studies of recovered COVID-19 patients.

Given the large number of individuals affected by the pandemic, understanding the long-term pulmonary consequences of COVID-19 is essential. Early identification of functional impairment may facilitate timely intervention through pulmonary rehabilitation and targeted clinical management.

Need for the Study

Although the acute clinical manifestations of COVID-19 have been widely studied, the long-term respiratory consequences of the disease remain an area of ongoing investigation. Patients recovering from moderate to severe COVID-19 pneumonia may experience persistent pulmonary symptoms and reduced exercise capacity even after clinical recovery.

The underlying mechanisms responsible for these persistent symptoms are thought to involve residual inflammation, fibrosis, and damage to the alveolar-capillary membrane. Such pathological changes may lead to restrictive lung disease and impaired gas diffusion. Identifying these functional abnormalities is important for guiding long-term patient care and rehabilitation strategies.

Pulmonary function tests provide an objective method for assessing lung function after recovery from respiratory illness. However, data regarding pulmonary function outcomes following COVID-19 infection remain limited in many regions, particularly in developing countries.

Evaluating pulmonary function abnormalities in recovered patients can help determine the prevalence and severity of long-term respiratory impairment. Such information may contribute to improved follow-up protocols, early detection of complications, and development of rehabilitation programs aimed at restoring respiratory function.

Therefore, the present study was undertaken to assess pulmonary function in patients who recovered from moderate to severe COVID-19 pneumonia and to determine the pattern of lung function abnormalities observed during follow-up.

Review of Literature (ROL)

Recent research has increasingly focused on the long-term respiratory effects of COVID-19 infection. Follow-up studies of hospitalized patients have demonstrated persistent abnormalities in pulmonary function tests months after recovery.

Huang et al. reported that reduced diffusion capacity was one of the most common pulmonary abnormalities observed in patients recovering from COVID-19 infection. The study highlighted the importance of long-term follow-up in patients who experienced severe disease.

A multicenter study conducted by Wu et al. in 2023 evaluated pulmonary function in patients six months after COVID-19 infection and found that a significant proportion of individuals demonstrated restrictive ventilatory defects and reduced diffusion capacity.

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Similarly, a systematic review published in 2024 concluded that impaired diffusion capacity and reduced lung volumes are among the most frequently reported abnormalities in post-COVID patients. The review emphasized the role of pulmonary rehabilitation and monitoring in managing these long-term complications.

Another prospective cohort study conducted in Europe demonstrated that structural lung abnormalities detected on imaging were associated with impaired pulmonary function during follow-up. Patients who had experienced severe COVID-19 pneumonia were more likely to develop persistent lung impairment.

These studies collectively indicate that pulmonary function abnormalities are common among survivors of moderate and severe COVID-19 infection. However, additional studies are needed to better understand the prevalence, severity, and pattern of these abnormalities in different populations.

Objectives

1. To evaluate pulmonary function abnormalities in patients recovering from moderate and severe COVID-19 pneumonia.
2. To identify the pattern of pulmonary function impairment following COVID-19 infection.
3. To assess the prevalence of restrictive, obstructive, and mixed ventilatory defects among recovered patients.
4. To evaluate diffusion capacity abnormalities in post-COVID patients.

METHODOLOGY

Study Design

This investigation was conducted as a prospective observational study.

Study Setting

The study was carried out at Government Medical College (GMC), Anantnag, in patients admitted to the designated COVID facility of the hospital for a period of 1 year (2021-2022).

Study Population

Patients admitted to the COVID facility with laboratory-confirmed SARS-CoV-2 infection were screened for eligibility. Diagnosis of COVID-19 infection was confirmed using reverse transcription polymerase chain reaction (RT-PCR) or rapid antigen testing (RAT) in accordance with national diagnostic guidelines.

Classification of COVID-19 Severity

Patients were categorized as **mild, moderate, or severe** according to national clinical management guidelines.

Mild Disease

Patients with uncomplicated upper respiratory tract infection presenting with symptoms such as fever, cough, sore throat, nasal congestion, malaise, or headache without evidence of breathlessness or hypoxia.

Moderate Disease

Patients with pneumonia presenting with fever, cough, dyspnea, or hypoxia with oxygen saturation less than 94% on room air and respiratory rate greater than or equal to 24 breaths per minute.

Severe Disease

Patients with clinical signs of pneumonia along with one of the following:

- Respiratory rate greater than 30 breaths per minute
- Severe respiratory distress
- Oxygen saturation below 90% on room air

Mild cases were managed either in COVID care centers or through home isolation with appropriate monitoring.

Inclusion Criteria

- Patients aged 18 years and above
- Confirmed moderate or severe COVID-19 pneumonia
- Patients without pre-existing pulmonary disease

Exclusion Criteria

- Patients with underlying lung diseases such as COPD or interstitial lung disease
- Patients requiring mechanical ventilation during hospitalization

Pulmonary Function Testing

Pulmonary function tests were performed at least two months after hospital admission. The testing included:

- Spirometry
- Lung volume measurement
- Diffusion capacity assessment (DLCO)

Patients were advised to avoid bronchodilator use on the day of testing or the preceding night.

Pulmonary function testing was performed according to European Respiratory Society (ERS) guidelines.

Interpretation of Spirometry

Spirometry results were categorized into four groups:

Normal Pattern

FEV1/FVC ratio greater than 70% and FVC greater than 80% predicted.

Restrictive Pattern

FEV1/FVC ratio greater than 70% with FVC less than 80% predicted.

Obstructive Pattern

Airway obstruction defined as FEV1/FVC ratio less than 70%.

Mixed Pattern

Combination of restrictive and obstructive defects defined as FVC less than 80% predicted and FEV1/FVC ratio less than 70%.

Diffusion Capacity

Diffusion capacity was evaluated using DLCO values.

- DLCO $\geq$ 80% predicted – Normal
- DLCO <80% predicted – Impaired diffusion capacity.

Data Analysis:

Table1: Gender characteristics

Males	Females	total
66 (60%)	44 (40%)	110

The study results revealed that out of 110 subjects, 60%(66) were males and 40%(44) were females

Table2: Patient characteristics

Age group (years)	Male	female	Moderate symptoms	Severe symptoms	Total	P value
15-24	1		1		1	
25-34	3	1	4		4	
35-44	3	4	6	1	7	
45-54	7 (7 < 50)	4 (1 < 50, 3 > 50)	10	1	11	
55-64	19	13	27	5	32	
65-74	21	14	28	7	35	
75-84	6	5	6	5	11	
>85	6	3	4	5	9	
	66	44	87	23	110	

The study results revealed that the Age of the patients ranged from 21 to 94 years with a mean age of 63.8 $\pm$ 14.5 years. The mean ages of males (63.6 $\pm$ 15.2) and females (64.1 $\pm$ 13.6) were not significantly different (p = 0.86). Majority of the patients, 77 (70%) , belonged to 50 to 80 year age group. Symptoms were moderate in 87 (79.1%) and severe in 23 (20.9%) patients.

Table3: Patient characteristics

Patient Characteristic	Total (110)	Moderate symptoms	Severe symptoms	p value
Age (years) ,mean $\pm$ sd				
COMORBIDITY				
Hypertension	28	19	9	
Diabetes mellitus	21	8	13	
Coronary artery disease	7	5	2	
ESRD	2	1	1	
Rheumatic heart disease	1	1		
Dilated cardiomyopathy	5	3	2	
Active or past smoking history	46	22	24	

Table4: Spirometry interpretation

Pattern	Moderate symptoms	Severe symptoms	total
Normal	85 (97.7%)	17 (73.9%)	102 (92.7%)
Restrictive	1 (1.15%)	5 (21.7%)	6 (5.5%)
Obstructive	1 (1.15%)	1 (4.4%)	2 (1.8%)
Total	87	23	110

Table5: Diffusion

DLCO	Moderate symptoms	Severe symptoms	total	P value
DLCO <80%	3 (3.5%)	8 (34.8%)	11 (10%)	
DLCO >80%	84 (96.5%)	15 (65.2%)	99 (90%)	
Total				

RESULTS

A total of 110 patients with confirmed COVID-19 infection who fulfilled the study criteria were included in the analysis. Among these patients, 66 (60%) were males and 44 (40%) were females, indicating a male predominance in the study population.

Demographic Characteristics

The age of the patients ranged from 21 to 94 years, with a mean age of 63.8 ± 14.5 years. The mean age among males was 63.6 ± 15.2 years, while the mean age among females was 64.1 ± 13.6 years. Statistical comparison revealed no significant difference between the mean ages of males and females ($p = 0.86$).

Most patients in the study belonged to the 50–80 year age group, accounting for 77 patients (70%) of the total population. Only 20 patients (18.2%) were younger than 50 years, whereas 90 patients (81.8%) were older than 50 years.

Disease Severity

Based on clinical classification at the time of admission:

- 87 patients (79.1%) had moderate COVID-19 disease
- 23 patients (20.9%) had severe COVID-19 disease
- Co-morbidities

Several comorbid conditions were identified among the patients.

The most common comorbidity observed was hypertension, present in 28 patients (25.45%), followed by diabetes mellitus in 21 patients (19.1%).

Other comorbid conditions included:

- Coronary artery disease – 7 patients

- Dilated cardiomyopathy – 5 patients
- End-stage renal disease – 2 patients
- Rheumatic heart disease – 1 patient

Among patients with diabetes mellitus, 13 patients (61.9%) developed severe disease, indicating a higher frequency of severe illness in this subgroup.

A history of active or past smoking was present in 46 patients (41.81%), suggesting a significant prevalence of smoking exposure among the study population.

Spirometry Findings

Pulmonary function tests were performed one year after hospital admission.

Overall, 102 patients (92.7%) demonstrated normal spirometry results.

When stratified by disease severity:

Moderate Disease

Among 87 patients with moderate disease:

- 85 patients (97.7%) had normal pulmonary function
- 1 patient (1.15%) had a restrictive pattern
- 1 patient (1.15%) had an obstructive pattern
- Severe Disease
- Among 23 patients with severe disease:
- 17 patients (73.9%) had normal pulmonary function
- 5 patients (21.7%) demonstrated a restrictive ventilatory defect
- 1 patient (4.4%) showed an obstructive pattern
- Overall spirometry interpretation revealed:
- Normal pattern: 102 patients (92.7%)
- Restrictive pattern: 6 patients (5.5%)
- Obstructive pattern: 2 patients (1.8%)

Restrictive abnormalities were more frequently observed among patients who had experienced severe COVID-19 illness.

Diffusion Capacity

Diffusion capacity of the lungs for carbon monoxide (DLCO) was also evaluated.

Overall findings showed:

- DLCO <80% (impaired diffusion): 11 patients (10%)
- DLCO ≥80% (normal diffusion): 99 patients (90%)
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Moderate Disease

Among patients with moderate disease:

- 3 patients (3.5%) had impaired DLCO
- 84 patients (96.5%) had normal diffusion capacity
-

Severe Disease

Among patients with severe disease:

- 8 patients (34.8%) had impaired DLCO
- 15 patients (65.2%) had normal DLCO

Impaired diffusion capacity was therefore significantly more common among patients with severe COVID-19 illness compared with those with moderate disease.

DISCUSSION

The present study evaluated pulmonary function outcomes among patients who recovered from moderate and severe COVID-19 infection. Pulmonary function testing was performed one year after hospitalization in order to assess long-term respiratory sequelae.

The demographic profile of the study population showed a male predominance, with males accounting for 60% of the total participants. Similar observations have been reported in several previous studies investigating COVID-19 outcomes. A large cohort study by Huang et al. published in *The Lancet Respiratory Medicine* reported that males were more frequently affected by severe COVID-19 illness, which has been attributed to differences in immune response, lifestyle factors, and comorbidities.

The mean age of patients in the present study was approximately 64 years, and the majority of individuals belonged to the 50–80 year age group. This finding is consistent with earlier reports demonstrating that older adults represent the group most vulnerable to severe COVID-19 infection and its complications.

Hypertension and diabetes mellitus were the most common comorbid conditions identified in the study population. These findings are comparable to those reported in multiple international studies evaluating risk factors for severe COVID-19 disease. In particular, diabetes mellitus has been associated with a higher risk of severe infection and poorer outcomes due to impaired immune function and increased inflammatory responses.

Pulmonary function testing revealed that most patients demonstrated normal spirometry results one year after infection, with over 92% of the total population showing normal pulmonary function. These results suggest that many patients with moderate disease experience substantial recovery of lung function over time.

However, restrictive ventilatory defects were more frequently observed among patients who had experienced severe COVID-19 illness. Approximately 21.7% of patients with severe disease demonstrated restrictive abnormalities, which may reflect residual interstitial changes or fibrotic remodeling within the lungs.

These findings are consistent with previous research examining pulmonary outcomes after COVID-19 infection. A study conducted by Wu et al. and published in the *European Respiratory Journal* reported that a subset of patients recovering from severe COVID-19 pneumonia developed persistent restrictive ventilatory defects during follow-up.

Diffusion impairment was another important finding in the present study. Ten percent of patients demonstrated reduced DLCO, indicating impairment of gas exchange across the alveolar-capillary membrane. Notably, diffusion abnormalities were significantly more common among patients who had experienced severe disease.

Reduced diffusion capacity has been identified as one of the most frequent pulmonary function abnormalities following COVID-19 infection. A follow-up study conducted by Mo et al. and published in *Clinical Infectious Diseases* reported that diffusion impairment persisted in a substantial proportion of patients several months after recovery.

Similarly, a large cohort study published in *Nature Medicine* by Shah et al. found that patients recovering from severe COVID-19 pneumonia frequently exhibited reduced DLCO during long-term follow-up. These findings support the hypothesis that COVID-19 can cause persistent injury to the alveolar-capillary membrane and pulmonary vasculature.

The results of the present study therefore align with existing literature demonstrating that while many patients recover normal pulmonary function after COVID-19 infection, those with severe disease remain at risk for long-term respiratory impairment.

CONCLUSION

The present study demonstrates that the majority of patients recovering from moderate and severe COVID-19 infection exhibit normal pulmonary function one year after hospitalization. However, a subset of patients—particularly those who experienced severe disease—develop persistent abnormalities in lung function, including restrictive ventilatory defects and impaired diffusion capacity.

These findings suggest that severity of initial infection plays a significant role in determining long-term pulmonary outcomes. Patients with severe COVID-19 pneumonia appear to be at greater risk of developing residual lung impairment. Long-term follow-up using pulmonary function testing may therefore be beneficial for identifying individuals who require further evaluation or rehabilitation.

Recommendations

1. Long-term pulmonary follow-up should be considered for patients recovering from severe COVID-19 infection.
2. Pulmonary function testing should be included as part of routine follow-up evaluation in patients with persistent respiratory symptoms.
3. Pulmonary rehabilitation programs may be beneficial for patients with residual respiratory impairment.
4. Further multicenter studies with larger sample sizes are recommended to better understand long-term pulmonary outcomes following COVID-19 infection.

Limitations

Several limitations of the present study should be acknowledged.

First, the sample size was relatively small, which may limit the generalizability of the findings.

Second, the study was conducted at a single center, and therefore the results may not represent outcomes in other populations.

Third, pulmonary function testing was performed only once during follow-up, and serial testing could provide a better understanding of the progression or recovery of lung function over time.

Finally, radiological correlation with high-resolution CT imaging was not included, which could have provided additional information regarding structural lung abnormalities.

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