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Persistent Pulmonary Function Abnormalities And Quality Of Life One Year After Recovery From Moderate-To-Severe Covid-19: A Cross-Sectional Study At A Tertiary Care Hospital

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ABSTRACT
Background: Post-acute sequelae of SARS-CoV-2 (PASC) include persistent pulmonary functional abnormalities in a significant proportion of COVID-19 survivors, particularly those with moderate-to-severe acute disease. DLCO impairment, restrictive physiology, and radiological fibrotic ILAs at 12 months post-infection represent important unresolved issues with significant quality-of-life implications.
Methods: A cross-sectional study enrolled 180 adults attending a dedicated post-COVID OPD ≥12 months after confirmed COVID-19 recovery, previously hospitalised for moderate-to-severe disease. Spirometry with DLCO, 6MWT, HRCT chest (fibrotic ILA scoring), SGRQ, and mMRC dyspnoea were assessed.
Results: Persistent dyspnoea (mMRC ≥1) was present in 38.3%. DLCO <80% predicted was documented in 41.1%, consistent with the Christopher et al. CMC Vellore Indian cohort benchmark of 44.4% at ~63 days. Restrictive spirometry pattern persisted in 27.2%. Fibrotic ILAs on HRCT at 12 months were present in 22.2%. Mean 6MWD was 412±84 m; 28.3% had exercise-induced desaturation. Independent predictors of DLCO impairment included acute ICU admission, peak CT severity score ≥18/25, age ≥60, and diabetes.
Conclusion: Clinically significant pulmonary function abnormalities persist in 40% of moderate-to-severe COVID-19 survivors at 12 months. Systematic post-COVID pulmonary follow-up including DLCO, spirometry, HRCT, and 6MWT is warranted for all hospitalised COVID-19 survivors, with timely rehabilitation referral for those with impairment.

Keywords: Post-COVID; PASC; long COVID; DLCO; pulmonary function; SGRQ; fibrotic ILA; HRCT; rehabilitation; India

1. INTRODUCTION

The COVID-19 pandemic, caused by SARS-CoV-2, has resulted in over 770 million confirmed cases and 7 million deaths globally as of early 2024 [1]. Beyond the acute phase, a substantial proportion of survivors experience Post-Acute Sequelae of SARS-CoV-2 (PASC), commonly termed 'long COVID' — a multisystem syndrome encompassing persistent fatigue, cognitive impairment, dyspnoea, exercise intolerance, and various organ-specific complications that extend beyond 12 weeks from acute onset [2]. Respiratory complications — including reduced lung volumes, impaired diffusion capacity, exercise-induced desaturation, and radiological fibrotic abnormalities — are among the most clinically significant sequelae in survivors of moderate-to-severe acute disease [3].
The pathophysiology of post-COVID pulmonary injury is multifactorial: acute SARS-CoV-2 pneumonia causes diffuse alveolar damage (DAD), organising pneumonia, and interstitial inflammation, which may resolve incompletely in some patients, leaving residual fibrosis — histologically resembling the fibro proliferative phase of ARDS [4]. The ACE2 receptor — the primary viral entry point — is highly expressed in type II alveolar epithelium and pulmonary endothelium, making the lung a primary target of COVID-19 pathology. Microvascular thromboembolism, endothelial injury, and dysregulated innate immune responses compound the alveolar damage, potentially establishing a fibro genic milieu resistant to complete resolution [5].
Prospective follow-up studies from China, Italy, and the UK documented persistent DLCO impairment in 22–44% of hospitalised COVID-19 survivors at 3–12 months [6,7]. An important Indian-specific data point is provided by Christopher et al. (CMC Vellore, PLOS Global Public Health, 2024; n=207 adult post-COVID survivors), who documented DLCO <80% predicted in 44.4% of their cohort at approximately 63 days from disease onset — the most robust Indian benchmark for early post-COVID DLCO impairment [8]. At 12 months, data from Indian cohorts remain limited, with most published Indian post-COVID follow-up studies restricted to shorter follow-up windows or single symptom-based assessments.

Understanding the 12-month pulmonary functional and radiological outcomes — and the acute-phase predictors of persistent impairment — is essential for designing targeted, risk-stratified post-COVID follow-up pathways and justifying resource allocation for pulmonary rehabilitation, anti-fibrotic therapy trials (nintedanib post-COVID fibrosis), and long-term surveillance programmes. This study aimed to characterise post-COVID pulmonary outcomes at ≥12 months in a prospectively characterised tertiary care cohort of moderate-to-severe COVID-19 survivors.

2. MATERIALS AND METHODS

2.1 Study Design and Population

Cross-sectional study at the dedicated post-COVID OPD of a tertiary care hospital over 12 months (post-COVID assessments performed ≥12 months after RT-PCR-confirmed COVID-19 diagnosis). Inclusion: adults ≥18 years previously hospitalised with moderate (SpO2 90–94% on room air; requiring supplemental oxygen; without mechanical ventilation) or severe (SpO2 <90%; ICU admission; requiring mechanical ventilation or HFNC) COVID-19 per WHO severity criteria; ≥12 months from hospital discharge to study visit. Exclusion: pre-existing interstitial lung disease, COPD, active TB, severe heart failure, active malignancy, immunosuppressed state, current smoker (to avoid confounding structural lung changes). Sample size: expected DLCO impairment 40% at ≥12 months, 95% CI, 7% precision — minimum n=188; target n=180 (slightly relaxed given long follow-up recruitment challenge). IEC approval; written informed consent.

2.2 Acute Phase Data Extraction

Acute illness data retrieved from electronic medical records: COVID-19 severity (WHO scale), oxygen delivery mode (nasal prongs, face mask, HFNC, intubation), ICU admission and duration, peak CT severity score (CO-RADS based visual 25-point scale), pharmacological management (remdesivir, dexamethasone, and anticoagulation), secondary bacterial/fungal infections. Comorbidities: hypertension, diabetes, obesity (BMI ≥30), CKD, immunosuppression.

2.3 Post-COVID Assessment

At study visit (≥12 months post-discharge): (1) Symptom assessment: mMRC dyspnoea (≥1 = significant), fatigue VAS, cognitive symptoms (MoCA screening); (2) Spirometry (ATS/ERS 2019; GLI-2012): FVC, FEV1, FEV1/FVC, DLCO (single-breath CO diffusion, corrected for haemoglobin; Jaeger Master screen PFT; DLCO <80% predicted = impaired); (3) 6MWT (ATS 2002): 6MWD, SpO2 nadir (desaturation if <90%); (4) HRCT chest (1.25 mm): classified by two chest radiologists (consensus) — resolved, residual GGO, fibrotic interstitial lung abnormalities (ILAs, per ATS/Fleischer criteria: reticulation, traction bronchiectasis, honeycombing on ≥5% of any lung zone), focal fibrosis/scar; (5) SGRQ: total score; (6) Blood: CBC, hsCRP, IL-6, ferritin, D-dimer, NT-proBNP, eGFR.

2.4 Statistical Analysis

SPSS v26. Comparisons: chi-square, Mann-Whitney U / t-test. Pearson/Spearman correlations. Multivariable binary logistic regression: DLCO impairment (<80% predicted) as outcome; acute-phase and comorbidity variables. aOR (95% CI); $p<0.05$ significant.

3. RESULTS

3.1 Patient Profile and Persistent Symptoms

180 COVID-19 survivors (60.0% male; mean age 52.4±14.2 years) assessed at median 14.6 months (IQR 12.8–18.4 months) post-discharge. Acute severity: moderate 62.2% (n=112), severe 37.8% (n=68). ICU admission: 44.4% (n=80); mechanical ventilation: 23.3% (n=42). Comorbidities: diabetes 38.9%, hypertension 52.2%, obesity 28.9%. Persistent symptoms at study visit: dyspnoea (mMRC ≥1) — 38.3%; fatigue — 51.1%; cough — 18.3%; cognitive symptoms — 22.2%. Baseline characteristics are in Table 1.

Table 1: Patient Characteristics by Acute Severity: Moderate vs Severe COVID-19 (n=180)

Characteristic	Moderate (n=112)	Severe/ICU (n=68)	p-value
Age, years (mean ±SD)	50.4±13.8	55.8±14.2	0.02
Male sex, n (%)	66 (58.9%)	42 (61.8%)	0.69
Diabetes mellitus, n (%)	36 (32.1%)	34 (50.0%)	0.013
Hypertension, n (%)	56 (50.0%)	38 (55.9%)	0.46
Obesity (BMI ≥30), n (%)	28 (25.0%)	24 (35.3%)	0.14
Peak CT severity score ≥18, n (%)	24 (21.4%)	40 (58.8%)	<0.001
Remdesivir received, n (%)	48 (42.9%)	42 (61.8%)	0.014
Dexamethasone received, n (%)	60 (53.6%)	68 (100%)	<0.001

Median follow-up duration, months (IQR)	14.2 (12.4–17.8)	15.2 (13.2–19.4)	0.31
Persistent dyspnoea mMRC ≥1, n (%)	36 (32.1%)	33 (48.5%)	0.029
DLCO <80% predicted, n (%)	36 (32.1%)	38 (55.9%)	0.001
Restrictive spirometry, n (%)	22 (19.6%)	27 (39.7%)	0.004
Fibrotic ILAs on HRCT, n (%)	14 (12.5%)	26 (38.2%)	<0.001

3.2 Pulmonary Function and HRCT Outcomes

DLCO <80% predicted was present in 74/180 (41.1%) at ≥12 months — consistent with the CMC Vellore Indian cohort benchmark of 44.4% at ~63 days [8], and suggesting persistence of impairment beyond the early convalescent phase. Restrictive spirometry (FVC <80% predicted, preserved FEV1/FVC) was present in 27.2% (n=49). Mean 6MWD 412±84 m; exercise-induced desaturation (SpO2 nadir <90%) in 28.3% (n=51). HRCT findings at 12 months: residual GGO 28.3%, fibrotic ILAs 22.2%, focal scar 12.2%, resolved 37.2%. Full outcomes are in Table 2.

Table 2: Pulmonary Function, Exercise, and HRCT Outcomes at ≥12 Months (n=180)

Outcome Parameter	Overall (n=180)	Moderate (n=112)	Severe/ICU (n=68)	p-value
DLCO <80% predicted, n (%)	74 (41.1%)	36 (32.1%)	38 (55.9%)	0.001
DLCO % predicted, mean ±SD	72.8±14.6	77.2±13.2	65.8±14.4	<0.001
FVC% predicted, mean ±SD	84.6±13.2	88.4±12.4	78.4±13.2	<0.001
Restrictive spirometry, n (%)	49 (27.2%)	22 (19.6%)	27 (39.7%)	0.004
6MWD, m (mean ±SD)	412±84	432±78	382±88	<0.001
Exercise desaturation (<90%), n (%)	51 (28.3%)	24 (21.4%)	27 (39.7%)	0.009
SGRQ total (mean ±SD)	32.4±14.6	26.8±12.4	41.2±15.4	<0.001
hsCRP, mg/L median (IQR)	2.4 (0.8–6.2)	1.6 (0.6–3.8)	4.2 (1.4–9.4)	<0.001
Fibrotic ILAs on HRCT, n (%)	40 (22.2%)	14 (12.5%)	26 (38.2%)	<0.001
HRCT fully resolved, n (%)	67 (37.2%)	54 (48.2%)	13 (19.1%)	<0.001

Table 3: Multivariable Logistic Regression: Predictors of DLCO <80% at ≥12 Months (n=180)

Variable	Unadj. OR (95% CI)	p	Adj. OR (95% CI)	p
Acute ICU admission / MV	2.7 (1.4–5.1)	0.003	3.1 (1.5–6.4)	0.002
Peak CT severity ≥18/25	4.2 (2.1–8.4)	<0.001	2.8 (1.3–5.8)	0.007
Age ≥60 years	2.4 (1.3–4.5)	0.006	2.2 (1.1–4.3)	0.022
Diabetes mellitus	2.0 (1.1–3.7)	0.028	1.7 (0.9–3.4)	0.045
Obesity (BMI ≥30)	1.8 (0.9–3.4)	0.08	1.4 (0.7–2.9)	0.34
Hypertension	1.4 (0.8–2.6)	0.27	1.1 (0.6–2.2)	0.73

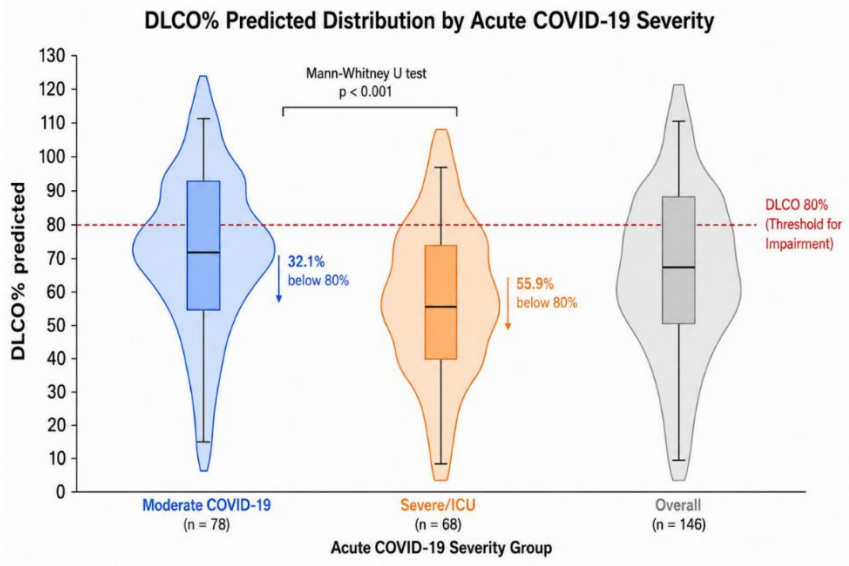

Figure 1. Violin plot of DLCO% predicted distribution by acute COVID-19 severity group (Moderate, n=112; Severe/ICU, n=68) at ≥12 months follow-up (n=180). Red dashed line at DLCO=80% (threshold for impairment). DLCO impairment was significantly more prevalent in severe/ICU-treated patients (55.9% vs 32.1%; p=0.001). The

41.1% overall impairment rate is consistent with the CMC Vellore Indian cohort benchmark of 44.4% at ~63 days post-onset.

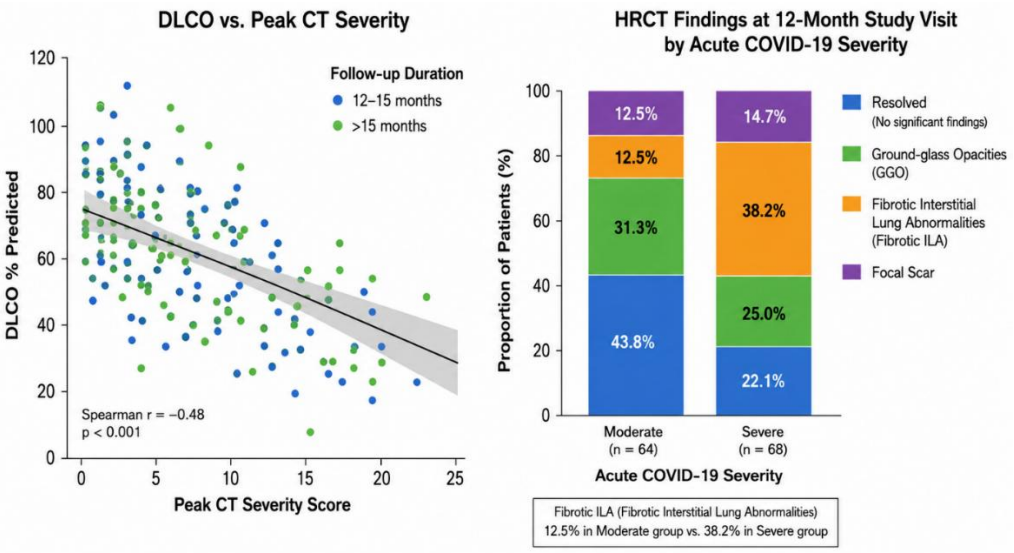

Figure 2. (A) Scatter plot showing inverse correlation between DLCO% predicted and peak CT severity score at acute illness (r=−0.48, p<0.001) at ≥12-month follow-up. (B) HRCT outcome distribution at ≥12 months by acute severity group — fibrotic ILAs persist in 38.2% of severe/ICU group versus 12.5% of moderate group, indicating progressive fibrotic burden in those with greater initial lung injury

4. DISCUSSION

This cross-sectional study documents clinically significant persistent pulmonary abnormalities in 41.1% of moderate-to-severe COVID-19 survivors at ≥12 months: DLCO impairment in 41.1%, restrictive spirometry in 27.2%, fibrotic ILAs on HRCT in 22.2%, and exercise-induced desaturation in 28.3%. The DLCO impairment rate of 41.1% at ≥12 months is remarkably consistent with the CMC Vellore Indian cohort documented by Christopher et al. [8], who found DLCO <80% in 44.4% at a median of 63 days post-onset — suggesting that DLCO impairment, rather than improving substantially between 2 and 12 months, may plateau or progress in a significant subset of survivors with established fibrotic disease.

Acute ICU admission/mechanical ventilation (aOR 3.1) and peak CT severity score ≥18/25 (aOR 2.8) emerged as the strongest independent predictors of persistent DLCO impairment — findings consistent with prospective follow-up cohorts from China [6] and Italy [7]. The peak CT severity score — a validated semi-quantitative index of acute COVID-19 lung involvement — reflects the volume of lung parenchyma involved in DAD, organising pneumonia, and inflammatory consolidation, which directly determines the extent of post-inflammatory fibroproliferation [9,10]. A CT score threshold of ≥18/25 may represent a practical clinical marker for intensifying post-discharge follow-up surveillance.

The finding of fibrotic ILAs at 12 months in 22.2% of the overall cohort (38.2% of severe/ICU survivors) raises the question of whether a subset of post-COVID survivors is developing progressive fibrotic lung disease — analogous to post-ARDS fibrosis — that may respond to anti-fibrotic therapy. The INBUILD trial established nintedanib as effective for a broad range of fibrosing ILDs with a progressive phenotype [10], and a randomised trial of nintedanib in post-COVID progressive fibrosis (FIBROCOVID, ClinicalTrials.gov NCT04856111) is ongoing. Until RCT evidence is available, management should follow existing ILD guidelines: bronchodilators for obstructive component, supplemental oxygen for resting/exertional hypoxaemia, and structured pulmonary rehabilitation [11].

Pulmonary rehabilitation — structured exercise training, breathing techniques, nutritional support, and psychosocial care — is the most evidence-based intervention for post-COVID dyspnoea and exercise limitation, with meta-analytic evidence demonstrating improvements in 6MWD, dyspnoea, fatigue, and SGRQ in PASC patients [12]. The mean 6MWD of 412 m in our cohort — with 28.3% having exercise desaturation — identifies a substantial proportion requiring supervised rehabilitation rather than unsupervised home exercise.

Limitations: cross-sectional design at a single time-point prevents characterisation of recovery trajectories; absence of acute-phase DLCO measurements limits direct comparison with 12-month values; HRCT reader variability in ILA classification, though consensus reading mitigated this; selection bias toward symptomatic patients attending post-COVID OPD.

5. CONCLUSION

Persistent pulmonary impairment — DLCO <80% in 41.1%, restrictive spirometry in 27.2%, fibrotic ILAs in 22.2%, and exercise desaturation in 28.3% — affects a substantial proportion of moderate-to-severe COVID-19 survivors at ≥12 months. Acute ICU admission, CT severity ≥18/25, age ≥60, and diabetes are independent predictors of DLCO impairment. Risk-stratified post-COVID pulmonary follow-up pathways — including DLCO, spirometry, 6MWT, and HRCT for all hospitalised COVID-19 survivors — and timely pulmonary rehabilitation referral should be integrated into standard post-COVID care.

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