ORIGINAL ARTICLE

Clinical symptoms and radiological sequels after SARS-CoV-2 pneumonia: A longitudinal study

Symptômes cliniques et séquelles radiologiques après une pneumonie SARS-CoV-2 : Une étude longitudinale

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Abstract

Introduction: The long-term effects of COVID-19 have been recognized as a significant public health issue, particularly for hospitalized patients who may experience persistent symptoms and lung complications. This study aimed to determine the prevalence of persistent clinical symptoms and determine the predictive factors of persistent CT scan abnormalities (PCA) after COVID-19 pneumonia.

Methods: This was a longitudinal cohort study of patients followed up after being hospitalized for confirmed SARS-CoV-2 pneumonia. Patients were assessed for persistent clinical symptoms at one month and for PCA at four months. A logistic regression model was employed to assess the relationship between PCA and explanatory variables.

Results: A total of 240 patients were included. The sex ratio was 1.75, with a mean age of 57.6(± 11.5) years. The median length of stay was 10 [7–15] days. Initial CT scans revealed severe impairment in 23%. After one month, 75.8% had at least one persistent symptom. Hyperventilation syndrome was diagnosed in 15.4% of patients. At four-month follow-up, CT scan showed that 65% of patients had PCA.

Factors associated with PCA, included age (p=0.001), initial dyspnea (p=0.021), length of hospital stay (p=0.001), an initial CT Severity Score (CTSS)≥ 50 (p=0.047), a low FEV1 (p=0.022), a low Total Lung capacity (TLC) (p=0.035) and impairment in DLCO (p=0.012). Logistic regression identified older age (OR=1.05 [1.02;1.08], p= 0.01), longer hospital stay (OR=1.12 [1.04;1.21], p= 0.003), and dyspnea (OR=3.11 [1.28;7.52],p= 0.012) as independent predictive factors of PCA.

Conclusion: clinical and radiological long-term sequelae of COVID-19 are frequent, particularly in older patients, those with dyspnea, or with extended hospital stays.

Keywords: SARS-CoV-2, Pneumonia, Sequels, Chest CT scan, Respiratory Function Tests

Résumé

Introduction: Les effets à long terme de la COVID-19 sont désormais reconnus comme un enjeu majeur de santé publique, en particulier pour les patients hospitalisés. Cette étude visait à déterminer la prévalence des symptômes cliniques persistants et à identifier les facteurs prédictifs d'anomalies persistantes au scanner (PCA) après une pneumonie due à la COVID-19.

Méthodes: Il s'agit d'une étude de cohorte longitudinale portant sur des patients suivis après une hospitalisation pour une pneumonie confirmée à SARS-CoV-2. Les patients ont été évalués pour les symptômes cliniques persistants à un mois et pour les PCA à quatre mois. Un modèle de régression logistique a été utilisé pour analyser la relation entre les PCA et les variables explicatives.

Résultats: Au total, 240 patients ont été inclus. Le sex-ratio était de 1,75, avec un âge moyen de 57,6 (± 11,5) ans. La durée médiane d'hospitalisation était de 10 [7–15] jours. Les scanners initiaux ont révélé une atteinte sévère dans 23 % des cas. Après un mois, 75,8 % des patients présentaient au moins un symptôme persistant. Un syndrome d'hyperventilation a été diagnostiqué chez 15,4 % des patients. Au suivi de quatre mois, le scanner a montré que 65 % des patients avaient des PCA.

Les facteurs associés aux PCA incluaient l'âge (p=0,001), la dyspnée initiale (p=0,021), la durée d'hospitalisation (p=0,001), un score de gravité initial au scanner (CTSS) ≥ 50 (p=0,047), un VEMS bas (p=0,022), une capacité pulmonaire totale (CPT) basse (p=0,035) et une altération de la DLCO (p=0,012). La régression logistique a identifié l'âge avancé (OR=1,05 [1,02;1,08], p=0,01), une hospitalisation prolongée (OR=1,12 [1,04;1,21], p=0,003) et la dyspnée (OR=3,11 [1,28;7,52], p=0,012) comme facteurs prédictifs indépendants des PCA.

Conclusion: Les séquelles cliniques et radiologiques à long terme de la COVID-19 sont fréquentes, en particulier chez les patients âgés, ceux présentant une dyspnée ou ayant eu une hospitalisation prolongée.

Mots clés: SARS-CoV-2, Pneumonie, Séquelles, Tomodensitométrie thoracique, Exploration fonctionnelle respiratoire

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Introduction

Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a global pandemic[1]. While extensive documentation exists regarding the acute phase of the disease—ranging from asymptomatic infection in most patients (80%) to mild symptoms (15%) and, in the most severe cases (5%), acute respiratory failure requiring invasive mechanical ventilation[2]—the long-term sequelae of COVID-19 have emerged as a significant concern. The World Health Organization (WHO) defined the Post-acute COVID-19 condition, commonly known as Long COVID, as the persistence or emergence of new symptoms three months after the initial SARS-CoV-2 infection, lasting for at least two months without an alternative explanation.

Despite growing awareness, significant gaps remain in understanding the long-term impact of COVID-19 [3] on patients' health, including clinical and psychological manifestations, as well as overall quality of life. Long COVID has been linked to a complex interplay of factors, including cellular damage, dysregulated immune responses characterized by inflammatory cytokine production, and a procoagulant state, all of which may contribute to persistent symptoms and complications [4,5]. In this context, further research is critical to identify the clinical features, risk factors, and long-term outcomes of the disease. Such insights are essential for informing targeted interventions and developing effective strategies regarding management and rehabilitation [6].

This study aimed to identify the clinical characteristics of patients recovering from COVID-19 pneumonia. This included assessing clinical symptoms, functional and mental health status, pulmonary function, and radiological findings. Secondarily, the study aimed to determine the prevalence of persistent CT scan abnormalities in patients with post-COVID-19 pneumonia and identify associated risk factors.

Methods

Study Design

We conducted a longitudinal cohort study of patients who were hospitalized for COVID-19 pneumonia between September 2020 and June 2021.

We included patients aged 18 years and older with confirmed SARS-CoV-2 pneumonia who actively participated in post-COVID-19 follow-up appointments. The confirmation of SARS-CoV-2 pneumonia included the detection of the viral genome in the upper airways using RT-PCR on nasopharyngeal swabs, complemented by a chest CT scan indicating the presence of lung damage.

We didn't include patients who declined to participate, those with incomplete medical records or missing data, patients without confirmed SARS-CoV-2 infection, and those with normal chest CT scans at admission.

Follow-up assessments were conducted at the pulmonology outpatient clinic between October 2020 and December 2021. All patients were contacted according to their discharge date as documented in the medical record. The follow-ups were scheduled for one month and four months.

Data Collection

The clinical information of the patients included in the study was systematically documented.

The first step of our study involved collecting demographic and clinical characteristics of patients during the acute phase of COVID-19 pneumonia. Patients were asked about the following symptoms: fever, cough, fatigue, chest tightness, myalgia, dyspnea, diarrhea, nausea/vomiting, ageusia, anosmia, headache, arthralgia, and dizziness. Additionally, dyspnea was evaluated using the modified Medical Research Council (mMRC) dyspnea scale. Severity indicators for acute COVID-19 pneumonia were recorded, including oxygen therapy (low-flow or high-flow), intensive care unit (ICU) admission, anticoagulation therapy, and complications such as pulmonary embolism.

At the one-month follow-up, a physician administered a post-COVID questionnaire (Appendix 1). Responses were recorded as "yes" or "no," and the questionnaire included the same symptoms assessed during the initial evaluation. The mMRC scale was used to evaluate the evolution of dyspnea [7].

Patients underwent an arterial blood gas (ABG) test to measure the levels of various gases in the blood. The following measures were taken: PaO2: The partial pressure of oxygen in the arterial blood, PaCO2: The partial pressure of carbon dioxide in the arterial blood, pH: The acidity or alkalinity of the blood, HCO3-: The bicarbonate level in the blood.

The Nijmegen score assessed the clinical probability of Hyperventilation Syndrome (HVS) according to 16 items and was performed at the M1 follow-up by a healthcare professional. A score > 22/64 is suggestive of HVS [8].

Screening for Post-Traumatic Stress Disorder (PTSD) was conducted using the Arabic-validated Diagnostic and Statistical Manual of Mental Disorder (DSM-5) Checklist. A diagnosis of PTSD was made when the score was > 32 [9–11].

Functional Status was assessed using the Post-COVID-19 Functional Status (PCFS) score [12], a self-administered five-item questionnaire validated in Arabic. It evaluates functional limitations, such as lifestyle and activity changes. Patients were graded from 0 (no limitations) to 4 (severe limitations).

The final step of our study involved a comprehensive four-month follow-up, focusing on respiratory functional and radiological evaluations. Pulmonary function was assessed using spirometry, with some patients also undergoing plethysmography and diffusing capacity of the lungs for carbon monoxide (DLCO) measurements. Key parameters included forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio, vital capacity (VC), residual volume (RV), total lung capacity (TLC), and DLCO, measured in liters (L) and mmol/(min*kPa), respectively. These measurements

followed American Thoracic Society and European Respiratory Society guidelines[14,15] and were expressed as percentages of predicted values, with impairment defined as values below the lower limit of normal (LLN) per Global Lung Function Initiative Network (GLI) reference values [16]. Respiratory impairments were categorized as restrictive (TLC < LLN), obstructive (FEV1/FVC < LLN), or diffusion-related (DLCO < LLN).

The radiological assessment included chest CT scans, interpreted by radiologists using the CT severity score (CTSS) to classify pneumonia extent during the acute phase: mild (<10% parenchymal involvement), moderate (10–24%), wide (25–49%), severe (50–74%), or very severe (≥75%) [17,18]. Follow-up CT scans evaluated clearance or repair signs, with abnormalities classified based on ground-glass opacity (GGO), parenchymal bands/atelectasis, bronchiectasis, condensation, and reticulation/fibrosis [19].

Data Analysis

Quantitative variables were presented as means ± standard deviations (SD) for normally distributed data and as medians with interquartile ranges (IQR) for non-normally distributed data. Qualitative variables were described using frequencies and percentages.

The normality of continuous data was assessed using the Shapiro-Wilk and Levene tests. Unpaired Student T-test, Welch T-test, or Mann-Whitney U-test were used according to data distribution to compare continuous outcomes. Baseline demographic data and follow-up data between groups with and without persistent CT scan abnormalities were compared. Chi-squared or Fisher's exact test was used accordingly to compare discrete outcomes.

Patients were stratified into two groups based on their chest CT scan findings at the 4-month follow-up evaluation:

Group 1 (G1): Patients with abnormal CT scans and group 2 (G2): Patients with normal CT scans. This stratification allowed the identification of predictive factors for persistent CT scan abnormalities in post-COVID-19 patients.

An analytical study was conducted to assess the relationship between persistent CT scan abnormality and different explanatory variables independently. Variables with a significance threshold p-value set at 0.05 were considered significant and introduced into the model.

A multivariate logistic regression model was performed to assess the relationship between persistent CT scan abnormality and explanatory variables.

Data were checked for multicollinearity using the Belsley-Kuh-Welsch technique. A p-value of 0.05 was considered statistically significant for the multivariate analysis. The statistical analysis was performed using R software, version 3.6.3.

Ethical considerations

The study protocol was reviewed and approved by the Ethical Committee of our institution.

Conflicts of interest

We declare that there are no conflicts of interest.

Results

Descriptive Statistics

A total of 240 patients were included in this study. The sex ratio was 1.75. The mean age of patients was 57.6 (± 11.5) years, with extremes ranging from 28 to 86 years. A total of 63 participants (26.25%) were over 65 years. The main demographic and clinical characteristics of the population are shown in table I.

Table 1. Demographic and Clinical Characteristics of the Study Population

Characteristics	N (%) or mean ± SD
Age	57.6 ± 11.5
Gender	
Male	153 (63.75)
Female	87 (36.25)
Tobacco(pack/year)	27 ± 19
Active smokers	89 (37)
BMI	30,2 ±5
Obesity (BMI>30kg/m²)	166 (48.3)
Comorbidities:	
None	74 (30,8)
=1	69 (28,75)
≥2	111(46,25)
Hypertension	98(40,83)
Diabetes Mellitus	85(35.42)
Dyslipidemia	45(18.75)
Asthma	20(8.33)
Anxiety	14(5.83)
Coronary disease	17(7)
Kidney disease	9(3.75)
Hypothyroidism	6(2.5)
Cancer	5(2)
Family history of severe form of SARS-CoV-2 infection	51(21.25)
Family history of death from SARS-Cov-2 infection	30(12.5)

During the acute phase, most patients (95%) were admitted to the Department of Pulmonary Medicine, with a median length of stay (LOS) of 10 [7–15] days, while 12 (5%) were transferred to the ICU, where the median LOS was 20 [11–33] days.

High-flow oxygen therapy was required by 90 patients (37.5%), and pulmonary embolism (PE) was diagnosed via chest CT scan in 21 patients (8.75%). Those with PE received curative anticoagulation for a median duration of 135 [13–180] days. Among the remaining patients, 119 (49.5%) received prophylactic anticoagulation for a median duration of 10 days [10–17.25], while 10 (4.1%) were administered therapeutic doses for a median duration of 13 days [10.25–26.25]. All patients exhibited symptoms during the acute phase (Table II).

The CT scans found 12 (5%) patients with mild impairment and 53 (22%) with moderate impairment.

A total of 105 (43.75%) had a wide impairment, representing the most dominant group. Severe alteration was shown in 55 (23%) patients, while 15 (6.25%) had very severe impairment.

Table 2. Clinical Symptoms During the Acute Phase and at One-Month Follow-Up

Clinical Symptoms	N (%)	
	Acute phase	One month Follow-up
Fatigue	195 (81.2)	51 (21.2)
Dyspnea	190 (79.1)	130 (54.1)
mMRC		
0:	50 (20.8)	110 (45.8)
1:	28 (11.6)	57 (23.7)
2:	29 (12)	60 (25)
3:	49 (20.4)	11 (4.5)
4:	84 (35)	2 (0.8)
Myalgia	163 (67.9)	47 (19.5)
Fever	159 (66.2)	2 (0.8)
Weight loss	158 (65.8)	7 (2.9)
Arthralgia	142 (59.1)	48 (20)
Headache	141 (58.7)	36 (15)
Cough	138 (57.5)	32 (13.3)
Ageusia	100 (41.6)	9 (3.7)
Dizziness	99 (41.2)	33 (13.7)
Concentration difficulty	99 (41.2)	60 (25)
Chest tightness	99 (41.2)	45 (18,7)
Anosmia	96 (40)	12 (5)
Diarrhea	90 (37.5)	12 (5)
Heart palpitation	83 (34.5)	34 (14.1)
Nausea /vomiting	76 (31.6)	5 (2)
Hyperventilation syndrome	-	35/227 (15.4)
PTSD > 32	-	105/231 (45,4)
PCFS		
0	-	108 (47)
1	-	37 (16.1)
2	-	38 (16.5)
3	-	37 (16.1)
4	-	10 (4.3)

During the first follow-up, the post-Covid questionnaire showed that among the included patients, 182 (75.8%) had at least one persistent symptom, with dyspnea being the most prevailing in 130 (54.1%).

The mMRC dyspnea scores changed in grades with grade 1 in 57 (23.7%) patients, followed by 60 (25%) for grade 2, 11 (4.5%) for grade 3, and 2 (0.8%) for grade 4.

The results of the Nijmegen score were available for 227 (94.58%). Based on the results, 35 (15.4%) were diagnosed with hyperventilation syndrome.

The arterial blood gas test showed that 24 (22.22%) had hypocapnia and nine (8.33%) had hypoxia.

The results of the PTSD Checklist DSM-5 (PCL-5) revealed that 105 (45.4%) scored above the cutoff score, indicating a probable diagnosis of PTSD.

The PCFS showed that 47% of patients had no functional limitations and only 4.3% had extremely severe functional limitations.

At the four-month follow-up appointment, spirometry testing was conducted on 105 patients and 80% had normal respiratory function.

Lung diffusion capacity for carbon monoxide (DLCO) measurement was performed on 44 patients and 45.4% of them had lung diffusion impairment.

Total lung capacity (TLC) was performed on 46 (43.8%) of the 105 patients and showed that 20 (43.4%) had TLC below LLN.

One hundred eighty (75%) patients received a CT examination. Sixty-three (35%) had normal chest CT scans (G2) and 117 (65%) with persistent CT scan abnormalities (G1). The most common feature found was ground glass opacities (GGO), present in 60 patients (51.2%), with 21 (17.9%) of them having bilateral GGO. Additionally, 26 (22.2%) showed bronchiectasis, 19 (16.2%) had condensation, 23 (19.6%) exhibited signs of fibrosis/ reticulation, and 16 (13.6%) had parenchymal bands/ atelectasis.

Analytic statistics

In the multivariate analysis, three factors were identified as independent predictors of persistent CT abnormalities following COVID-19 pneumonia. Advancing age was associated with an increased likelihood of persistent abnormalities, with each additional year conferring a 5% increase in odds (OR = 1.05, 95% CI: 1.02–1.08, p = 0.01). Similarly, a prolonged hospital stays independently correlated with a higher risk, with each additional day increasing the odds by 12% (OR = 1.12, 95% CI: 1.04–1.21, p = 0.003). Furthermore, the presence of initial dyspnea emerged as a strong predictor of persistent radiological abnormalities., with an OR of 3.11 (95% CI: 1.28–7.52, p = 0.012).

However, other factors such as the initial CT severity score (CTSS ≥ 50), PaO2 < 70 mmHg, and FEV1< LLN while significant in univariate analysis, did not retain statistical significance in the multivariate model (p=0.16,p=0.23, and p= 0.58 respectively).

Discussion

Our study aims to explore the long-term effects of COVID-19 up to four months after infection. It came out that a large proportion of patients had prolonged symptoms, functional limitations, pulmonary function impairment, and radiological sequelae after recovering from COVID-19 pneumonia. At the initial follow-up, 75.8% of patients had at least one persisting symptom, with dyspnea being the most common. The study also showed that 45.4% of the individuals experienced PTSD symptoms. Furthermore, 65% of patients had persistent radiological abnormalities, 20.4% had restricted ventilatory patterns, and 42.2% had lung diffusion impairment. The study also identified factors associated with persistent CT scan abnormalities, including age, length of hospital stay, and dyspnea which showed statistical significance in the multivariate analysis.

Follow-up

Persistent symptoms like cough, dyspnea, and fatigue are commonly reported in post-COVID-19 patients after hospital discharge for similar follow-up periods to our study ranging from 30 to 56 days [20–22].

Table 3. Comparison between characteristics of patients in G1 and G2

	Univariate analysis			Multivariate analysis	
Characteristics	**G1**	**G2**	**p-value**	**Odds Ratio[CI95%]**	**p-value**
Age, yr.	60.37 ± 10.91	54.27 ± 12.88	0.001	1.05 [1.02;1.08]	0.01
Gender (Male)	80 (68.37%)	39 (61.9%)	0.478		
Active smokers	46 (39.31%)	23 (36.5%)	0.834		
BMI	30.22 (± 5.15)	29.51 (± 4.07)	0.49		
Comorbidities ≥1	82 (70.08%)	40 (63.5%)	0.38		
Number of comorbidities	1,46 (±1.22)	1,31 (±1.34)	0.342		
Hypertension	48 (41,03%)	23 (37.7%)	0.702		
Diabetes mellitus	44 (37.61%)	17 (26.98%)	0.204		
Dyslipidemia	18 (15.38%)	13 (20.63%)	0.495		
Asthma	10 (8.55%)	3 (4.76%)	0.547		
Anxiety	5 (4.27%)	4 (6.35%)	0.722		
Coronary disease	9 (7.69%)	2 (3.17%)	0.333		
Length of stay (days)	12.79 (±7.42)	8.8 (±3.32)	0.001	1.12 [1.04;1.21]	0.003
ICU transfer	7 (5.98%)	1 (1.58%)	0.153		
Requiring high flow oxygen therapy	45 (38.46%)	20 (31.74%)	0.22		
Anticoagulant treatment	78 (66.66%)	39 (61.9%)	0.232		
Initial CT severity score (CTSS)≥ 50	40 (34.18%)	11 (17.46%)	0.047	1.86 [0.78;4.44]	0.16
Pulmonary embolism	11 (9.4%)	5 (7.93%)	0.786		
Fatigue					
Initial	93 (79.48%)	54 (85.71%)	0.472		
Follow-up	23 (19.66%)	15 (23.81%)	0.646		
Dyspnea					
Initial	102 (87.17%)	46 (73.02%)	0.021	3.11 [1.28;7.52]	0.012
Follow-up	69 (58.97%)	33 (52.38%)	0.488		
Fever					
Initial	68 (58.12%)	49 (77.78%)	0.513		
Follow-up	1 (0.85%)	0 (0.0%)	>0.999		
Weight loss					
Initial	79 (67.52%)	40 (77.78%)	0.647		
Follow-up	2 (1.71%)	2 (3.17%)	0.613		
Arthralgia					
Initial	67 (57.26%)	39 (61.9%)	0.704		
Follow-up	23 (19.66%)	14 (22.22%)	0.832		
Headache					
Initial	60 (51.28%)	43 (68.25%)	0.052		
Follow-up	17 (14.53%)	14 (22.22%)	0.273		
Cough					
Initial	66 (56.41%)	39 (61.9%)	0.623		
Follow-up	15 (12.82%)	10 (15.87%)	0.653		
Ageusia					
Initial	51 (43.58%)	25 (39.68%)	0.693		
Follow-up	6 (5.13%)	1 (1.59%)	0.424		
Dizziness					
Initial	49 (41.88%)	25 (39.68%)	0.863		
Follow-up	13 (11.11%)	10 (15.87%)	0.36		
Chest tightness					
Initial	50 (42.73%)	30 (36.51%)	0.672		
Follow-up	24 (20.51%)	2 (3.17%)	0.767		

Table 3. (following) Comparison between characteristics of patients in G1 and G2

	Univariate analysis			Multivariate analysis	
Characteristics	**G1**	**G2**	**p-value**	**Odds Ratio[CI95%]**	**p-value**
Anosmia					
Initial	49 (41.88%)	23 (36.51%)	0.557		
Follow-up	9 (7.69%)	2 (3.17)	0.333		
Diarrhea					
Initial	36 (30.76%)	28 (44,44%)	0.133		
Follow-up	7 (5.98%)	3 (4.76%)	>0.999		
Concentration Difficulty					
Initial	49 (41.88%)	27 (42.86%)	>0.999		
Follow-up	27 (23.08%)	15 (23.81%)	>0.999		
Heart Palpitation					
Initial	41 (35.04%)	22 (34.92%)	>0.999		
Follow-up	17 (14.53%)	10 (15.87%)	>0.999		
Nausea/vomiting					
Initial	33 (28.2%)	23 (36.51%)	0.346		
Follow-up	2 (1.71%)	2 (3.17%)	0.613		
Follow-up clinical symptoms ≥1	87 (74.35%)	45(71.43%)	0.62		
PH	7.43 (±0.0293)	7.44 (±0.024)	0.152		
Range	(7.31 ; 7.5)	(7.4 ; 7.51)			
PaO2, mmHg	87.44 (±18.0)	97.22 (±16.39)	0.036		
Range	(36.0 ; 165.0)	(76.0 ; 131.0)			
PaO2<70mmHg	9 (7.7%)	0 (0%)	0.028	1.24 [0.87;1.76]	0.23
PaCO2, mmHg	36.67 (±3.52)	39.47 (±13.26)	0.596		
Range	(26.0 ; 44.0)	(25.7 ; 98.0)			
PaCO2<35mmHg	19 (16.23%)	6 (9.52%)	0.262		
HCO3-	24.36 (±2.29)	24.28 (±3.88)	0.413		
Range	(17.0 ; 29.0)	(9.0 ; 29.6)			
Forced expiratory volume at the first second of exhalation (FEV1) < LLN	17 (14.5%)	3 (4.7%)	0.022	0.79 [0.43;1.56]	0.58
Forced vital capacity (FVC) < LLN	21 (17.9%)	7 (11.1%	0.121		
Total lung capacity (TLC) < LLN	16 (34.7%)	2 (4.3%	0.035	0.971 [0.0249; 37.94]	0.988
Diffusion capacity of the lung for carbon monoxide (DLCO) <LLN	18 (44.9%)	2 (4.5%)	0.012	2.99 [0.0787; 113.72]	0.555
Restrictive ventilatory pattern	17 (14.5%)	0 (0%)	<0.001	1.323 [2.135;3.421]	0.135

CI 95%: confidence interval at 95%

Persisting dyspnea and other functional respiratory complaints can be linked to hyperventilation syndrome (HVS) [24], contributing to a substantial exercise limitation [25].

Diagnosis is based on a positive score in the Nijmegen Questionnaire, with a sensitivity of 91% and specificity of 95% [26]. A recent study found that the prevalence of a positive score on the Nijmegen Questionnaire reached 20.7% in patients with previous history of SARS-CoV-2 infection [27], which is similar to our results and close to the prevalence of HVS in asthmatics patients [28].

Psychiatric consequences can also arise. Factors such as social isolation, fear of infecting others, and the stigma surrounding the illness can trigger symptoms. A study conducted by Fekih-Romdhane et al. [29] examined the prevalence of post-traumatic stress disorder (PTSD) in a cohort of 603 Tunisian individuals. The researchers found that 33% of the participants had PTSD. Although these findings are in line with our results, PTSD typically takes time to develop and can only be formally diagnosed after a minimum of 6 months [30], which necessitates extended follow-up.

Our data on persistent pulmonary function impairment showed that diffusion capacity was the most common anomaly on lung function tests, followed by restrictive ventilatory defects [31]. These findings are consistent with those of multiple studies, including the study by Hellemons et al. [32] which performed spirometry for 77 patients admitted for COVID-19 at 3 months follow-up visit and found that FVC was below the LLN in 25% of the patients, and FEV1 < LLN in 18% of the patients. Moreover, Bellan et al. [33] found that a significant proportion of COVID-19 survivors experienced respiratory or functional impairment 4 months after hospital discharge, with

51.6% of patients having impaired DLCO as the main functional impairment.

Research showed that many COVID-19 pneumonia patients hospitalized continue to show CT scan anomalies up to three months after discharge, likely due to post-organizing pneumonia, rather than fibrotic changes.

Our results are comparable to the meta-analysis by So et al. [34] investigating lung squeals of COVID-19, which included 13 studies that assessed the residual chest CT findings and showed that more than 50% of the recovered patients still had anomalies up to 3 months post-infection.

Predictors of persistent CT scan abnormality

Our study found that patients who had residual pulmonary parenchymal abnormalities on a 4-month follow-up had significantly older age, longer duration of hospitalization, more severe disease score on initial CT scan, higher prevalence of dyspnea at hospitalization, worse pulmonary function test parameters and lower mean PaO2 on arterial blood gas.

In the study by Tabatabaei et al. [35], investigating chest CT findings of COVID-19 pneumonia individuals at risk for residual abnormalities, fifty-two patients were followed up for three months post-infection.

Another similar study by Parry et al. [36], aimed to predict the persistence of lung anomalies on chest CT through medium-term follow-up after ≥ 3 months, and also found that patients with residual abnormalities were older, had lower oxygen saturation, longer hospital stay, and had a higher initial CT severity score.

However, some studies found that patients with residual abnormalities on CT scans had a higher rate of ICU admission [31,35,37,38] and more underlying medical conditions [35], this can be explained by the limited number of patients admitted to the ICU in our cohort, as well as the differences in patient population characteristics.

Correlation with lower pulmonary function test parameters up to 3 months after COVID-19 pneumonia was also reported. DLCO at follow-up was the most significant one, as it was found to be statistically significantly lower in patients who had residual pulmonary parenchymal anomalies on CT scans [37–43] as well as lower TLC, FEV1, FVC, and RV [37–39,43].

Strengths and Limitations

The strength of our study is the systematic approach and comprehensive assessment of the health status of patients with varying degrees of COVID-19 severity, allowing for a broad view of complications and sequels. According to recommendations and guidelines of the British Thoracic Society, it is reported that patients who experience persistent respiratory symptoms after being discharged from the hospital should undergo a thorough clinical assessment, pulmonary function evaluation, and a CT scan follow-up at around 12 weeks [34,44]. Imaging follow-up is recommended to be performed after that delay to allow resolution of the reversible inflammatory process and should be correlated with clinical findings and PFT.

The limitations of our study include the single-center design, the relatively small number of patients, and the exclusion of non-hospitalized patients which affect the generalizability of our findings. Moreover, the lack of a COVID–19 without pneumonia control group limits the ability to conclusively attribute the findings to the pneumonia COVID-19. Furthermore, the evaluation of persistent symptoms was limited to one month after the acute phase, thus not allowing for long-term monitoring of long COVID syndrome. While our study provides valuable insights, it is essential to acknowledge these limitations. Future research, including longer follow-up studies, is warranted to address these constraints and to elucidate the natural trajectories of recovery, identify predictors of complications, and develop strategies to mitigate morbidity.

Conclusion

The long-term effects of COVID-19 pose significant public health challenges, placing a substantial burden on healthcare systems. Our study revealed that one-month post-discharge, 75.8% had at least one persistent symptom. Additionally, 15.4% were diagnosed with hyperventilation syndrome, and 45.4% exhibited post-traumatic stress disorder (PTSD). Functional limitations were reported in 53% of patients, with 16.5% experiencing moderate to severe restrictions. By four months, 80% had normal respiratory function and 65% had persistent CT scan abnormalities. Factors linked to persistent CT were age, dyspnea, and hospital identified in multivariate analysis. These findings highlight the importance of prolonged and personalized medical follow-up, particularly for older patients, those with dyspnea, or those with extended hospital stays, to better manage long-term sequelae and optimize recovery.

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