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Spirometry correlation with the severity of the picture by tomography of post COVID-19 patients hospitalized from June 2020 to June 2021 one year after their condition at the Hospital General Regional 1 Carlos Mac Gregor Sánchez Navarro

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Abstract

The emergence of the SARS-COV-2 virus caused a high mortality rate worldwide and has resulted in alterations in the pulmonary function of post-COVID-19 patients in survivors. The most common pulmonary symptom reported after COVID-19 is dyspnea, which may persist

in 22.9% to 53% of patients 2 months after symptom onset. In addition to subjective symptoms, SARS- CoV-2 infection can cause long-term objective changes in pulmonary physiology. Some studies over the three years have confirmed alterations at the pulmonary level, for example, a reduction in DLCO may still be present in 11-45% of COV-19 survivors at 12 months, or the prevalence of impaired diffusing capacity and decreased FEV1/FVC ratio, However, there are other studies that defend that there is no alteration at 12 months in the control spirometry, the number of studies is limited to other populations, so this study aims to make a tomographic evaluation and its comparative spirometric evolution at one year in the population studied and expand knowledge on the impact of alveolar physiology.

Keywords: Post-COVID-19 syndrome, spirometry in COVID-19 patients, restrictive pattern.

Introduction

The appearance of the SARS-CoV-2 virus has caused a high mortality rate worldwide and has resulted in alterations in pulmonary function in survivors.

Chest CT findings in COVID-19 pneumonia are the expression of acute interstitial lung damage and resulting parenchymal changes caused by the cytokine storm triggered by virus internalization in pneumocytes, causing changes in the lung such as edema, hyaline membranes and alveolar cellular exudates, which are the substrate for the most common lung CT findings detected, such as ground glass and focal consolidation. Ground glass was the earliest abnormality, with an occurrence rate of up to 88%, while consolidations have been described in approximately 32% of patients. It has been documented both in isolation and in association with focal areas of consolidations, although pure consolidations are a rare finding. There are alveolar alterations such as ground glass, rounded, multifocal, with bilateral and peripheral pattern.

The lesions sometimes coalesce and condense forming areas of consolidated parenchyma that progressively organize to form thickening of the intralobulilar and intralobulilar septa called crazy paving. Also alterations of the interstitium, broncho vascular and pleura, thickening of the inter and intralobulbar septa which increase with the prolonged course of the disease and may be present in almost half of the patients. Airway alterations may be due to the presence

of air bronchogram associated to consolidated bronchograms, observing to a lesser extent the appearance of bronchiectasis (1).

There is thickening of the pleural wall which is related to the local inflammatory process. The appearance of fine subpleural lines is related to edema or incipient fibrosis and thickening, configuring the formation of parenchymal bands that reflect the presence of fibrosis and is usually associated with distortion of the pulmonary architecture. A frequently present sign is vascular thickening observed in some series with up to 70% of incidence (2).

The distribution of parenchymal lesions is commonly bilateral (88%), multilobar (78%) and peripheral (76%), with frequent involvement of the posterior regions of the lungs (80%). In addition, other chest CT findings, such as interlobular septum, thickening, bronchiectasis and halo sign, have been reported with lower prevalence. Specifically, a dilatation of subsegmental pulmonary vessels and parenchymal abnormalities have been documented as a possible effect of locally released proinflammatory factors (3).

During the peak of the pandemic, the CO-RADS scale was used, which provides a COVID-19 level of suspicion for pulmonary involvement based on features observed on non-contrast chest CT. The level of suspicion increases from very low (CO-RADS category 1) to very high (CO-RADS category 5); according to research on the utility of the scale in the acute phase of the pandemic, the performance of CO-RADS was very good, with an average AUC of 0.91 compared to RT-PCR and an AUC of 0.95.(4)

The most common pulmonary symptom reported after COVID-19 is dyspnea, which may persist in 22.9% to 53% of patients 2 months after symptom onset. In addition to subjective symptoms, SARS-CoV-2 infection can cause long-term objective changes in pulmonary physiology, present in up to 30% of patients 9 months after acute illness.

of patients 9 months after acute illness. About 68% of patients have at least one sequela at 6 months and almost half of those affected will persist with sequelae one year after infection; the most common are fatigue, dyspnea, cognitive complaints, anxious-depressive disorders and muscle weakness, which cause deterioration in quality of life.

Pulmonary function testing techniques are an important way to assess lung damage secondary to the acute episode; different types of respiratory function assessments can be performed objectively, with spirometry, diffusing capacity and lung volume measurement being the most commonly used pulmonary function tests (PFTs). Through spirometry, which provides specific information by itself, the diagnosis is determined with common patterns of

pulmonary alteration such as obstructive type ventilatory alteration and restrictive type ventilatory alteration.

In the obstructive type, the maximum expiratory flow is limited by airway obstruction or by a decrease in the elasticity of the lung parenchyma in the presence of a parallel deterioration of the lung volume and for this reason there is a decrease in the Forced Expiratory Volume in the first second (FEV1) and in the FEV1/FVC ratio, and these are the most important data. In the restrictive type of ventilatory alteration, there is a decrease in lung volume that may be due to multiple pathologies of the pulmonary parenchyma in the presence of deterioration, as well as inflammatory, infectious causes or due to deposit of some substances, alterations that course with a decrease in the volume of the thoracic cage and also, due to reactions to surgical interventions of the pulmonary parenchyma or residual lesions due to tuberculosis. Non-obstructive ventilatory impairment is defined by a reduced forced vital capacity (FVC) with an FEV1/FVC ratio above the lower limit of normal (LNN) or even the mean reference value. A restrictive disorder should be suspected when the FVC is below the LIN, the FEV1/FVC ratio exceeds its LIN and the flow-volume curve presents a convex morphology. However, it is only possible to confirm this circumstance if a reduction in total lung capacity (TLC) <5th percentile of the reference value is observed (5).

The coexistence of an obstructive and non-obstructive defect in a patient is defined when both FVC and FEV1/FVC ratio are below their respective LIN. To elucidate whether the origin is air trapping and hyperinflation or true restriction, a TLC measurement should be performed. In general, this guideline recommends confirming the presence of restriction when FVC or VCF are low by measuring TLC (6).

In patients followed within one year for acute respiratory failure syndrome that conditioned the stay in intensive care units, a significant reduction in pulmonary diffusion capacity of carbon monoxide (DLCO), abnormalities in pulmonary function, spirometric changes representing both restrictive (15% of patients) and obstructive (7% of patients) patterns were found; In the study of the natural history of pulmonary damage, an improvement in pulmonary sequelae was found in the pulmonary capacity of the month compared to the subsequent months after hospital discharge. A recent study conducted at the Department of Respiratory Physiology of the Institute of Respiratory Diseases (INER) found that lung function damage in patients recovered from severe pneumonia who were intubated or not, but were in critical care, showed small improvements in FEV1 and FVC and moderate improvements in the diffusion test for carbon monoxide (DLCO); however, in the six-minute

walk test the distance did not improve substantially. In addition, almost half of the patients had oxygen desaturations and delayed heart rate recovery; however, there are few one-year spirometric studies to determine long-term changes.

Material and Methods.

This is a quantitative, observational, analytical cohort, cross-sectional and retrospective study that included 78 post-COVID-19 patients from Hospital General Regional 1 Carlos Mac Gregor Sánchez Navarro, between January 2020 and December 2021 with ages between 18 and 80 years who required controls and monitoring for presenting signs and symptoms of COVID-19, During the study, epidemiological variables (height, weight, age and sex) were collected, as well as tomographic variables during hospitalization and spirometric variables one year after the resolution of the symptoms.

Patients with previous pulmonary disease, active respiratory infections (tuberculosis, norovirus, influenza), recent myocardial infarction (7 days), unstable angina, thoracic aortic aneurysm that has grown or is large (>6 cm), confused or dementia patients, recent surgery, acute diarrhea or vomiting, nausea, hypertensive crisis were excluded.

A binomial linear regression statistical analysis was performed to calculate the probability of presenting spirometric alterations secondary to moderate to severe COVID-19; the correlation of the severity of the condition with functional alteration was assessed through a scatter plot.

Objectives:

To examine and evaluate FVC, FEV1 and FEV1/FVC ratio by spirometry 12 months after the acute episode.

To evaluate the correlation between the degree of severity of the condition and the values obtained by spirometry.

To determine the correlation between the tomographic severity of COVID-19 and the values obtained by spirometry in patients diagnosed with post COVID-19.

Results of the follow-up group

The total of 60 patients included in the sample underwent a respiratory function evaluation one year after confirmation, via a positive SARS COV-2 antigen test and tomographic evaluation of the degree of severity of pulmonary involvement (period from June 2021 to June 2022). It is important to note that for this study the specific identification of the SARS COV-2 variant to which they tested positive was not considered relevant in order to make the sample more representative.

In the results of the tests (see Table 1) it was possible to identify that from the total number of samples, only 5% of the cases showed obstruction to the respiratory flow and about 20% showed restrictive behavior, which is not conclusive to assert that the restriction or obstruction could be related to SARS COV-2 infection (Figure 1).

Table 1. Obstructive/restrictive behavior observed in patients after a year of their first COVID-19 resolution

	FEV1/FVC			**Protocol results**		
	Average	PRE	POST	LOWER LIMIT	STATUS	CORADS
1	68.62%	67.90%	69.30%	62%	NORMAL	4
2	80.04%	77.50%	79.00%	70%	NORMAL	4
3	78.36%	77.50%	73.50%	70%	NORMAL	3
4	84.38%	83.70%	85.90%	70%	NORMAL	5
5	67.71%	77.80%	53.00%	70%	OBSTRUCTIVE	3
6	80.54%	76.30%	86.00%	67%	NORMAL	3
7	87.87%	84.60%	92.40%	72%	NORMAL	5
8	73.03%	73.00%	73.30%	65%	NORMAL	5
9	92.86%	92.30%	90.70%	64%	NORMAL	4
10	80.65%	76.90%	84.60%	70%	RESTRICTIVE	5
11	78.11%	78.90%	77.40%	70%	NORMAL	3
12	76.12%	80.90%	82.80%	64%	NORMAL	3
13	81.23%	82.10%	81.10%	65%	NORMAL	3
14	79.10%	82.50%	83.70%	67%	RESTRICTIVE	5

15	84.77%	83.00%	86.00%	63%	RESTRICTIVE	5
16	74.71%	83.30%	86.00%	64%	RESTRICTIVE	5
17	80.97%	78.70%	85.40%	70%	RESTRICTIVE	5
18	88.60%	89.60%	86.80%	65%	NORMAL	4
19	90.64%	89.30%	92.60%	70%	NORMAL	3
20	74.65%	73.20%	75.60%	67%	NORMAL	4
21	79.85%	79.40%	80.90%	63%	NORMAL	4
22	71.47%	78.80%	63.10%	65%	NORMAL	3
23	80.70%	75.20%	77.20%	66%	NORMAL	3
24	91.61%	69.10%	83.80%	62%	RESTRICTIVE	5
25	91.42%	73.20%	80.20%	65%	NORMAL	3
26	79.05%	79.00%	81.20%	67%	NORMAL	5
27	95.16%	97.20%	95.10%	70%	NORMAL	3
28	84.80%	82.90%	85.60%	68%	NORMAL	4
29	61.54%	62.00%	64.50%	63%	OBSTRUCTIVE	5
30	84.58%	85.10%	81.90%	72%	NORMAL	4
31	78.99%	80.20%	78.40%	70%	NORMAL	4
32	73.06%	72.80%	73.50%	67%	NORMAL	3
33	60.47%	59.70%	60.80%	66%	OBSTRUCTIVE	3
34	90.72%	88.30%	91.50%	67%	NORMAL	3
35	85.12%	86.50%	88.00%	63%	NORMAL	3
36	86.35%	87.10%	85.10%	65%	NORMAL	3
37	92.33%	92.80%	92.10%	65%	NORMAL	4
38	92.90%	87.50%	85.40%	70%	RESTRICTIVE	5
39	88.17%	89.90%	87.20%	70%	NORMAL	4
40	78.65%	81.00%	79.00%	68%	NORMAL	3
41	77.20%	78.90%	76.40%	67%	NORMAL	4
42	95.78%	97.10%	96.80%	65%	NORMAL	5
43	98.77%	91.20%	89.80%	70%	RESTRICTIVE	5

44	86.97%	88.20%	86.30%	64%	NORMAL	3
45	80.38%	90.10%	89.00%	67%	RESTRICTIVE	5
46	79.20%	80.50%	78.90%	63%	NORMAL	3
47	86.23%	86.30%	85.70%	65%	NORMAL	3
48	94.23%	95.60%	94.00%	65%	NORMAL	3
49	95.78%	97.20%	95.20%	64%	NORMAL	4
50	69.18%	93.50%	91.70%	68%	RESTRICTIVE	5
51	91.42%	91.80%	90.60%	67%	NORMAL	4
52	83.17%	89.80%	91.30%	68%	RESTRICTIVE	5
53	90.25%	92.40%	90.60%	65%	NORMAL	4
54	93.52%	95.30%	92.90%	65%	NORMAL	5
55	81.09%	82.20%	80.60%	67%	NORMAL	3
56	67.66%	90.30%	87.50%	63%	RESTRICTIVE	5
57	88.37%	89.50%	88.10%	63%	NORMAL	3
58	68.57%	87.60%	90.50%	64%	NORMAL	3
59	97.23%	86.40%	84.70%	70%	NORMAL	4
60	84.51%	86.70%	84.60%	66%	NORMAL	4

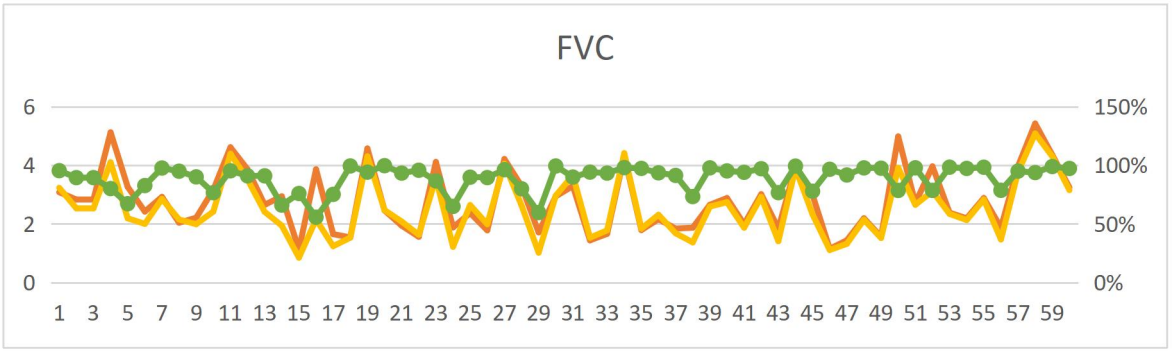

Figure 1 Pre vs Post spirometry data. %PRED as dotted line

Despite the confirmation of infection, 75% of the patients considered in this sample were within parameters defined as normal for the spirometry test and the average ranges were within the expected, which does not allow us to conclusively relate any behavior directly to the infection evolution.

Binomial linear regression was performed in an attempt to correlate the CORADS values obtained for the initial CT scans performed in the sample of 60 patients with the results of the control spirometry tests performed one year after discharge. For this purpose, a binomial category variable was used to identify those restrictive spirometries according to the lower limit defined by patient's age and weight and to perform the analysis on them.

As for the CORADS values that were identified in a well-defined range (3 to 5), were assigned with a non-binomial probability value, so that a correlation probability value of 1% was defined for patients with a CORADS 3 assessment; 2.5% for patients who showed a CORADS 4; and 5% for a CORADS 5 because this a type of lesion expected to affect the group studied the most.

As a result of the binomial linear regression, a p=0.216 was obtained, corresponding to 20% of patients who showed restrictive spirometry. In every case, these corresponded to a CORADS 5 assessment (Figures 5 & 6).

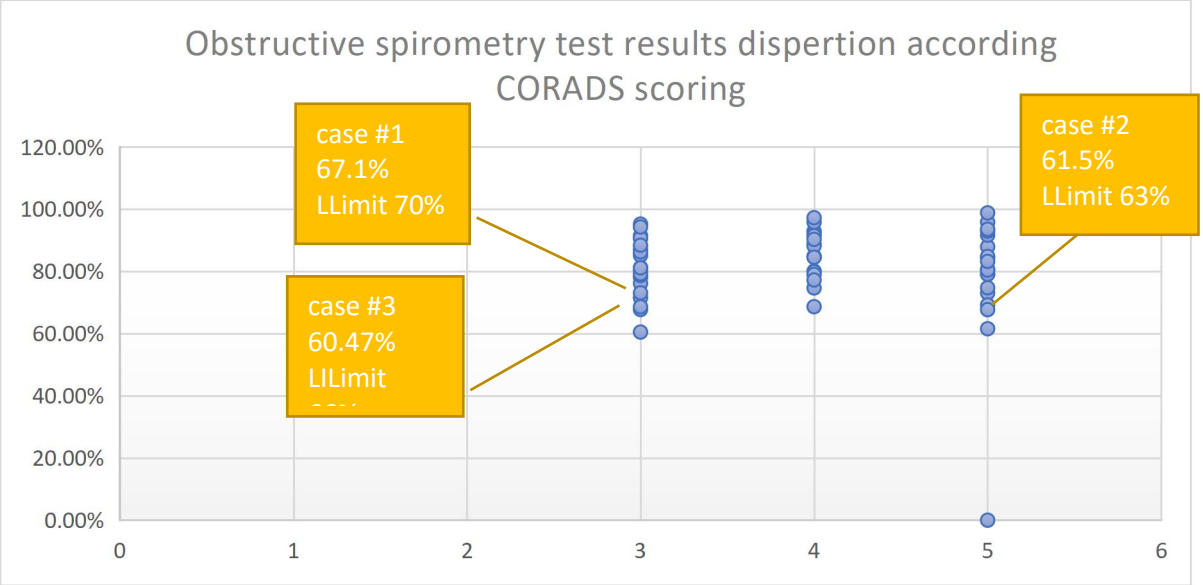

Figure 5. FEV1/FVC vs CORAD scoring dispertion

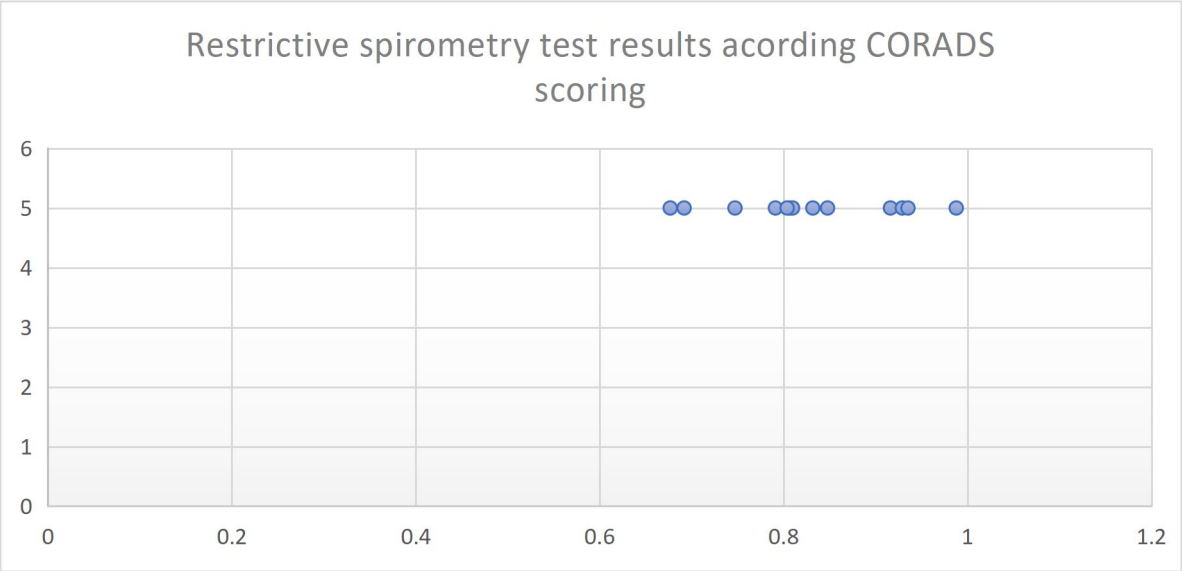

Figure 6. Every restrictive case had a CORAD score of 5 with a 21.6% correlation ratio.

Discussion

In the last few years, diverse studies have been conducted on the alterations of COVID sequelae to determine the functional restriction in multiple areas and due dyspnea is a constant point to highlight, several studies have been conducted around it, which will be discussed below.

Ahmed H et al, in 2020, published a meta-analysis of patients who survived previous viral pandemic outbreaks such as severe acute respiratory syndrome (SARS) and middle east respiratory syndrome (MERS) to gain insight into the pulmonary function status of survivors of both pandemics; concluding as common complications up to 6 months after discharge: impaired carbon monoxide diffusion capacity (prevalence 27%, 95 % confidence interval (CI) 15-45 %); and reduced exercise capacity (mean 6-min walk distance 461 m, CI 450-473 m). Pulmonary function impairments and functional limitation to exercise were similar among survivors of both pandemic outbreaks. Impairment was mainly restrictive in nature, with predominance of abnormalities in DLCO, CV and CLT compared to FEV1, thus supporting the etiopathogenesis of ARDS with parenchymal infiltration caused by infection. Although lung function improves with time, the results of the current meta-analysis showed that reduced DLCO may still be present in 11-45% of VOC survivors at 12 months. This is consistent with CT findings in other studies that have reported that pulmonary fibrosis may persist for up to 7 years (7).

Additionally, Vasconcello-Carrillo L, Torres-Castro R, Rivera-Lillo G, Solis-Navarro L, Puppo H, in 2020, presented a review article on the best tests in functional and respiratory assessment in post-COVID-19 patients, narrative review data and of which the most useful tests for pulmonary function assessment were spirometry and carbon monoxide diffusing capacity, while for functional capacity assessment were the six-minute walk test, the Sit-To-Stand test and the Bartel index. One of these studies reported 16% of diffusion capacity alterations in pulmonary function tests three months after discharge (8).

Huang Y et al. in 2020 published a research article evaluating the impact of COVID-19 on pulmonary function in the early convalescent phase. This study was conducted retrospectively at the Fifth Affiliated Hospital of Sun Yat Sen University through pulmonary function testing studies with serial assessments of spirometry, lung volumes, DLCO (diffusing capacity of carbon monoxide), six-minute walk distance, and computed axial tomography through tests performed 30 days after discharge, these identified that approximately three-quarters of patients with COVID-19 developed lung function impairment, the most common of which was impaired diffusing capacity and decreased FEV1/FVC ratio. (9,10).

However, during the early rehabilitation phase, the total lung severity score had no significant correlation with FEV1, FVC or DLCO which was inconsistent with previous research in SARS survivors, so it seems that the deterioration of lung function did not necessarily coincide with the severity of the disease, despite this, a fact to take into account is that the patients included in the research had treatment with glucocorticoids, which could improve the fibrosis process and therefore, the residual changes in the images of this new study.

Subsequently, another cross-sectional study of 40 patients was carried out on the follow-up of pulmonary function in post COVID-19 patients, after eight months of discharge, for which patients were selected who still persisted with discomfort and sequelae at eight months; of the sample, 22 patients still had physical and psychological symptoms and 9 had functional limitations; and although all had a normal forced vital capacity, in 22.5% a pulmonary capacity was found to be normal. 5% were found to have total lung capacity, DLCO and DLCO/VA below 80% of predicted values in 8 patients, another 8 patients by spirometry had FEV1/FVC below 70% of predicted values and 2 had COPD, asthma and smoking. On Chest CT (Computed Axial Tomography), 28 patients were normal, while 12 cases had abnormal CT at 8 months after discharge. In the end, it was concluded that patients who had severe COVID-19 had impaired lung function on DLCO test with persistent symptoms in daily life and higher total lung capacity compared to mild cases (11).

In another study, Zhao et al. performed a retrospective multi-center cohort that included 77 patients, although 22 were excluded, and the CT scans of 55 patients were analyzed and compared with pulmonary function tests by spirometry in all of them. Although most patients had no respiratory symptoms during follow-up, pulmonary function abnormalities were detected in 14 patients (25.45%). Abnormalities were observed in CPT in 4 patients (7.27%), FEV1 in 6 patients (10.91%), CFV in 6 patients (10.9%), DLCO in 9 patients (16.36%) and small airways function in 7 patients (12.73%).(12)

In an article published by Tabernero E et al., also in 2020, the alteration of pulmonary function in the early follow-up of patients with COVID-19 pneumonia was manifested and of a total of 850 patients admitted, 85% presented pneumonia without the need for ICU admission, recognizing the functional repercussion of COVID-19 pneumonia even in patients who did not require admission to the ICU. Of this population, 78.8% presented normal DLCO, only 7 patients presented DLCO less than 70% and only one patient presented moderate involvement with DLCO less than 60% in spirometry. On the other hand, FVC1 was normal in 100 cases (96%) and FEV in 93% of patients, only 11% presented FEV1/FVC less than 70% (13).

Mo X, Jian W, conducted a study in which 110 discharged cases were enrolled, including 24 cases of mild disease, 67 cases of pneumonia and 19 cases of severe pneumonia. The mean age of these cases was 49.1 years and 55 of them were women. The results showed abnormalities in DLCO of the predicted percentage in 51 cases (47.2%), total lung capacity (TLC) of the predicted percentage in 27 cases (25.0%), forced expiratory volume in 1s (FEV1) of the predicted percentage in 15 cases (13.6%), forced vital capacity (FVC) of the predicted percentage in 10 cases (9.1%), FEV1/FVC in five cases (4.5%) and small airway function in eight (7.3%), in the comparative table it can be observed that this trend of gradual decrease in DLCO level among patients was proportional to the severity status. The predicted TLC % value in cases of severe pneumonia was much lower than that in cases of pneumonia or mild disease, suggesting a greater deterioration of lung volume in severe cases, however, there were no significant differences with respect to FEV1, FVC, FEV1/FVC. (14)

Oriol Sibila, on the other hand, conducted a study in Barcelona that included 172 patients with a mean age of 56.1±19.8 years performed 3 months (101.5±19.9 days) after discharge, where 70% were diagnosed with severe COVID-19 and 43% were admitted to the intensive care unit (ICU). ICU length of stay was 14.6±27.3 days and in hospital 20.1±16.3 days with normal spirometry results in previously healthy patients, found FEV 1 of 94 [80-105] %, FVC 90 [80-

100] % of theoretical and FEV 1 /FVC 0 ratio, 80 [0.75-0.84] %), but DLCO was slightly reduced (77 [64-88]% of predicted) in males (76.9% vs 51.2%, p=0.005) with a history of cardiovascular disease (34.2% vs 9.4%, p=0.001) and diabetes (28.9% vs 12%, p=0.02). Similarly, those with reduced FVC were also more frequently male (76.3% vs 51.6%, p=0.008) with prior cardiovascular disease (29.7% vs 11.0%, p=0.009).(15)

Howarth T, Ben H, Perez A, Atos C, White E, Heraganahally S, in 2021, conducted an original article on the difference in outcomes through DLCO testing and total lung capacity between two populations of Indigenous Australians and Caucasian Australian adults; in the end, it was found that Indigenous Australian participants had reduced values on DLCO testing in the same manner as for total lung capacity data. They analyzed these results in both absolute and percentage values in both sexes and all ages compared to Australian Caucasian adults and absolute lower limit of normal values without demonstrating significant differences between some groups (16).

Sanchez C, in 2021, published an original article aimed to know the pulmonary function status in those patients recovered from COVID-19 based on a telemedicine approach. It was a study that included post-COVID-19 patients older than 18 years. Respiratory function tests were performed in pulmonary function laboratory. Of the sample of 26 patients, 88.4% had known comorbidity at the time of diagnosis, in the CT scan 38% had increased severity, spirometry with bronchodilator was performed in 80.7% of patients (2) and this was reported as normal in 61% (17) with suggestion of restriction in 38% (15), only 9.5% met reversibility criteria and diffusion disorders were found in 40% (18). The most frequent symptoms in post-COVID-19 patients were fatigue and dyspnea (2).

Fumagalli A et al. in 2021 investigated respiratory function at the time of clinical recovery, at 6 weeks, 6 months, and 12 months after discharge in patients who survived COVID-19 pneumonia. One case series consisted of 13 patients hospitalized with COVID-19 pneumonia. Baseline pulmonary function tests were 55.7 ± 15.6 for FEV1%, 68.6 ± 16.0 for FVC% and 1.2 ± 0.1 for FEV1/FVC%. Although lung function showed a small improvement after 6 weeks, patients experienced more significant improvement after 6 and 12 months in FEV1% (95.4 ± 13.7 and 107.2 ± 16.5, respectively; $p < 0.001$), FVC% (91.3 ± 14.5 and 105.9 ± 15.6; $p < 0.001$), and FEV1/FVC% values (1.04 ± 0.04 and 1.01 ± 0.05, respectively; $p < 0.001$). They concluded that COVID-19 pneumonia can result in significant alterations in lung function, with a primarily restrictive pattern, persisting in part at 6 weeks after recovery from the acute phase, but improving significantly over a 12-month follow-up period (19).

Thomas M, Price O, Hull J, in 2021, published a comparative study on post-COVID-19 recovery, and state that there is concern about possible long-term pulmonary sequelae and associated deterioration in functional capacity. Data published so far indicate that spirometric indices appear to be generally well preserved, but that a defect in diffusing capacity (DLCO) is a frequent abnormality identified in follow-up lung function; present in 20-30% of those with mild to moderate disease and in 60% of those with severe disease. Reductions in total lung capacity were frequently reported. Functional capacity is also often affected and data detailing gait test and cardiopulmonary exercise test outcome at follow-up are now beginning to emerge. In this review, we evaluate the published evidence in this area, to summarize the impact of COVID-19 infection on lung function and relate it to clinico-radiological findings and disease severity (20).

Polese J et al. developed, in 2021, findings on post COVID-19 patients with persistence of symptoms after hospital discharge and pulmonary function tests in which lung damage was evidenced with reduced FVC and total lung capacity. Likewise, with the DLCO test it was found that they were altered, which reflected a deficit in gas exchange and indicates the existence of pulmonary sequelae such as fibrosis; however, with a follow-up and long-term study of these patients post COVID-19 are being identified provide important data in the evolution and sequelae with results of pulmonary function tests with restrictive pattern and reduction of forced vital capacity (FVC) in 54% of individuals, with a mean FVC of 78±14%. A reduction in DLCO was observed in 79% (21).

Magdy D et al, investigated in 2022, the long-term effects of respiratory function and related physiological characteristics of survivors of COVID-19 disease that have not yet been studied in depth. They examined lung function and exercise capacity in 85 survivors with confirmed COVID-19, who were evaluated at the end of 3 and 6 months after disease onset. Of the total number of survivors, 48 (56.5%) were male. The mean (standard deviation) age was 34.6 (±9.9) years. 13 patients (15.2%) had medical comorbidities and their mean duration of hospitalization was 18.5 (±5.6) days. 25 (29.4%) required ICU admission, while 6 (7%) of them required invasive mechanical ventilation. No significant differences were observed between lung volume parameters. At 6 months, there was a significant reduction in carbon monoxide diffusing capacity (DLCO), $p = 0.02$. 25 (29.4%) of the patients had an altered DLCO ≤80% of the theoretical value. It concludes that of the survivors discharged with COVID-19, 23.5% had significant impairment of lung function diffusing capacity

abnormality. Exercise capacity and health status were significantly lower than those of a normal population after 6 months postinfection (22).

Celik E et al. in 2022 evaluated the association between COVID-19 and postinflammatory emphysematous lung alterations on low-dose follow-up CT scans. Consecutive patients with proven COVID-19 infection and a follow-up CT scan were retrospectively reviewed. The severity of lung involvement was classified as mild, moderate and severe. Total lung volume, emphysema volume and emphysema/lung volume ratio were quantified semi-automatically and compared interindividually between baseline and follow-up CT and with a control group of healthy patients of the same age and sex. Lung density was further assessed by drawing circular regions of interest (ROI) in unaffected regions of the upper lobes.

The study was performed in 32 individuals (mean age: 64 ± 13 years, 12 females) with at least one follow-up CT scan (mean: 52 ± 66 days, range: 5-259). In the overall cohort, total lung volume, emphysema volume and lung-to-emphysema volume ratio did not differ significantly between baseline and follow-up scans. In the subgroup of COVID-19 patients with follow-up > 30 days, emphysema volume was significantly higher compared with the subgroup with follow-up < 30 days ($p = 0.045$). Manually measured individual ROIs generally yielded lower attenuation values prior to COVID-19 pneumonia, but the difference was not significant between groups (all $p > 0.05$). They conclude that COVID-19 patients with follow-up CT > 30 days showed significant emphysematous lung alterations. These findings may help explain the long-term effect of COVID-19 on lung function and warrant validation by further studies (23).

Niyatiwatchanchai N et al., 2022, studied the early post-COVID-19 effects, especially in younger people, measured the early clinical impacts of post-COVID-19 pneumonia, comparing severe and non-severe patients. Through a cross-sectional study in adult patients admitted with COVID-19 pneumonia from April to May 2021. Demographic data, symptoms and signs, chest X-ray, pulmonary function tests (spirometry, impulse oscillometry), fractional exhaled nitric oxide and exercise capacity at one month after hospital discharge. The study included 25 age- and gender-matched healthy control subjects who were recruited for comparisons. Forced vital capacity was lower in the severe (88.3% of theoretical value) and non-severe (94.6% of theoretical value) group than in the healthy controls ($p = 0.001$). Six-minute walking distance was significantly shorter in the non-severe group, at 79.2m, and in the severe group, at 103.8m, than in healthy control subjects ($p < 0.001$). They concluded that adult patients with COVID-19, especially those with clinically severe pneumonia still had

residual symptoms and chest radiographic abnormalities, and lower exercise capacity, one month after hospital discharge (24).

Ye L et al. in 2022 studied patients to determine the effect of COVID-19 on lung function, with a retrospective analysis of 56 COVID-19-infected patients who were cured after clinical treatment at the Taizhou Public Health Medical Center in Zhejiang province. After three months of discharge, lung function, including inspiratory vital capacity, forced vital capacity, forced expiratory volume in the first second (FEV1), forced expiratory volume in the first second to inspiratory vital capacity (FEV1/IVC), mean peak expiratory flow (MEF), peak expiratory flow rate (PEF) and carbon monoxide dispersion (DLCO) were measured. 37 cases (66.1%) had pulmonary dysfunction, 22 patients (39.3%) with ventilatory dysfunction, 31 cases (55.4%) with small airway dysfunction and 16 cases (28.6%) with restricted ventilatory dysfunction combined with small airway dysfunction.

At 3 months after discharge, 24 of the 56 patients still had pulmonary dysfunction and all had small airway dysfunction, of which 10 patients (17.9%) had restricted ventilation dysfunction combined with small airway dysfunction. DLCO was measured three months after discharge, 29 patients (51.8%) had mild to moderate diffuse dysfunction. All lung function indices of 56 patients gradually recovered after 3 months after discharge, except FEV1/IVC, and the difference was statistically significant (< 0.05). It concludes that COVID-19 can cause lung function impairment, manifested as restricted ventilatory dysfunction, small airway dysfunction, and diffuse dysfunction. The lung function of most patients improved 3 months after clinical cure and discharge, although some patients remained with mild to moderate diffuse dysfunction and small airway dysfunction (25).

Desai A, Lavelle M, Boursiquot B, and Wan E, in 2022, stated that as our experience with this virus grows, so does our understanding of the short- and long-term complications of SARS-CoV-2 infection. Just as there is heterogeneity in the acute infectious phase, there is heterogeneity in the long-term complications observed after COVID-19 disease. Although COVID-19 can have far-reaching impacts throughout the body, it remains predominantly a respiratory disease. Many long-term pulmonary complications have been described following SARS-CoV-2 infection. These include, among others, dyspnea, ventilator dependence, oxygen dependence, pulmonary function test abnormalities, and fibrosis.(26).

During the present study, 60 spirometries at 1 year after hospital discharge of patients admitted to the hospital with a positive antigen test and CT scan were analyzed. Of these, 20% of the patients had a restrictive spirometry, which correlated positively with a restrictive

respiratory pattern in relation to the admission CT score in CORADS 5, and 8% had an obstructive pattern, of which CORADS 3 was determined in 2 cases and CORADS 5 in one of them, Based on the results obtained in previous studies, it can be presumed that long-term alterations secondary to physiological changes in most cases may remit in the short or medium term and that the probability of a long-term functional alteration may be 28% with a greater probability of showing a restrictive than an obstructive pattern, however, a relationship between the degree of severity by CT scan and the spirometric pattern at one year of evolution is not necessarily shown. It can be presumed that a CORADS 5 pattern has a probability of functional alteration of 20% with a tendency. To show a restrictive pattern.

Conclusions

In the study conducted in this health center, the results obtained are consistent with previously published studies, where there is a greater number of patients without long-term alterations in spirometric function, however, a higher percentage with restrictive sequelae and to a lesser extent of obstructive type, which are independent of the symptomatology found in patients and the CT scan recorded in the acute process of the disease, As shown in the graphs, ideally in a second scenario the results should be measured against alterations of the DLCO, which is the test with the greatest deterioration reported in previous evaluations, it is important to perform a comparative test of the results of spirometry compared to the 6-minute walk test, It is important to perform a comparative test of spirometry results in comparison with the 6-minute walk test, since clinical deterioration has been detected in spite of spirometric tests without alteration at one year or with alteration in mild percentage, however if the restrictive deterioration is correlated with an admission CT with CORADS of 5, more research is required in this regard and to expand the sample size to improve the external validity of the study.

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