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Assessment of Longterm Impact of Covid-19 on Pulmonary Functional Capacity

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Abstract

Background: In this study, we aimed to assess the prevalence and severity of respiratory impairments among individuals who were positive for COVID-19 in past and to investigate the association between disease severity during acute COVID- 19 infection and subsequent pulmonary function abnormalities. This study examines the complex aspects of how COVID-19 impacts the capacity of the lungs to function, investigating the underlying mechanisms, possible risk factors, and consequences for public health policies and clinical treatment.

Materials and Methods: This study was conducted as an observational study at the Department of Medicine, Gandhi Medical College, and associated Hamidia Hospital and RIRD, Bhopal. Detailed history was obtained and spirometry was done to assess lung function.

Results: The mean values of FVC (79.39%), FEV1 (71.09%), and FEV1/FVC ratio (77.42%) indicate varying degrees of pulmonary function impairment among the patients. There were significant differences in PFT parameters based on age, initial lung involvement, mask requirement, hospitalization requirement, and HRCT grading. Older age groups and those with severe initial lung involvement, oxygen requirement and hospitalization needs showed worse pulmonary function outcomes. Patients with symptoms such as fatigue, worsening symptoms after effort, fever, headache, sleep difficulties, depression/ anxiety, dizziness and difficulty in breathing had significantly lower PFT parameters, indicating poorer pulmonary function.

Conclusions: Our study highlights the significant and multifaceted long-term impacts of COVID-19 on pulmonary function among survivors. A substantial proportion of patients experienced persistent respiratory abnormalities, with restrictive lung disease being particularly prevalent. Pulmonary function tests revealed significant reductions in FVC, FEV1, FEV1/FVC and DLCO, underscoring the need for ongoing monitoring and rehabilitation. These findings highlight the necessity of comprehensive, long-term care, rehabilitation and

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follow-up for COVID-19 survivors to manage and mitigate the diverse and persistent sequelae of the COVID-19.

Keywords: long term impact of COVID 19, DLCO, pulmonary function tests, spirometry, severity

Introduction

COVID-19 predominantly affects the respiratory system, leading to the development of acute respiratory distress syndrome (ARDS), pneumonia, and pulmonary fibrosis. The initial infection sets off a series of inflammatory reactions, resulting in damage to the alveoli, decreased exchange of gases, and later dysfunction of the lungs. The degree of lung damage during the initial stage of illness might vary significantly, affecting the seriousness of long-term respiratory problems.[1-3] The term "Post-acute sequelae of COVID-19 (PASC)" refers to a range of respiratory issues that can occur after recovering from COVID-19. These complications can include ongoing difficulty breathing (dyspnoea), persistent cough, as well as restrictive and obstructive lung disorders.[4] Long-term investigations have shown that a significant majority of individuals who have recovered from COVID-19 continue to experience ongoing respiratory symptoms, even after the acute infection has resolved.[5] Furthermore, recent findings indicate a notable occurrence of interstitial lung abnormalities and pulmonary fibrosis in persons who are recuperating from severe COVID-19 pneumonia. This presents considerable difficulties for maintaining respiratory health in the long term.[6]

Multiple factors contribute to the variation in long-term pulmonary outcomes after contracting COVID-19. Old age, underlying respiratory disorders such as asthma or chronic obstructive pulmonary disease, obesity, and extended use of mechanical ventilation during severe illness are well-known variables that increase the likelihood of developing long-lasting pulmonary dysfunction. Moreover, socio-economic inequalities, environmental influences, and genetic predispositions can worsen the susceptibility of some groups to respiratory complications following COVID-19. This highlights the significance of focused treatments and fair healthcare availability. Efficient rehabilitation measures are crucial in reducing the long-term effects of COVID-19 on pulmonary function capability. Nevertheless, the remarkable increase in respiratory problems following COVID-19 has put a lot of pressure on healthcare resources and emphasized the need to create thorough post-acute care plans. It is essential to incorporate many disciplines such as pulmonology, respiratory therapy, physical therapy, and mental health in order to effectively address the unique requirements of those who have survived COVID-19 and promote comprehensive healing. [7,8]

To effectively deal with the lasting effects of COVID-19 on lung function, it is essential to adopt a comprehensive strategy that includes public health activities, research efforts, and regulatory changes. Longitudinal monitoring studies are essential for understanding the course of post-COVID respiratory complications and identifying risk variables that can be modified.[9] The COVID-19 pandemic has posed challenges to worldwide healthcare systems and has also aroused substantial worries about its potential long-term impact on individuals' health. Among the numerous issues that can occur after recovery, the effect on pulmonary function capacity is particularly worrisome. Gaining insight into the enduring effects of COVID-19 on pulmonary function is crucial for devising efficacious approaches to rehabilitate, manage, and prevent

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subsequent respiratory problems. In this study, we aimed to assess the prevalence and severity of respiratory impairments among individuals who were positive for COVID-19 in past and to investigate the association between disease severity during acute COVID- 19 infection and subsequent pulmonary function abnormalities. This study examines the complex aspects of how COVID- 19 impacts the capacity of the lungs to function, investigating the underlying mechanisms, possible risk factors, and consequences for public health policies and clinical treatment.

Materials And Methods

This study was conducted as an observational study at the Department of Medicine, Gandhi Medical College, and associated Hamidia Hospital and RIRD, Bhopal. Patients aged 18-60 years who had tested positive for COVID-19 and were discharged from Hamidia Hospital, reporting atleast 1 year after their date of positive report and were willing to participate in the study were included whereas patients with a prior diagnosis of any pulmonary disease were excluded from the study.

The study was conducted following approval from the Institutional Ethics Committee (IEC) of Gandhi Medical College, Bhopal. Informed consent was obtained from all participants, and patient confidentiality was maintained throughout the study. Data regarding sociodemographic variables, severity of COVID 19 infection etc. were collected during outpatient visits. Any reports pertaining to previous COVID infection were collected and findings were documented. Patients were questioned about their presenting complaints and underwent pulmonary function tests (PFT) to assess their pulmonary functional capacity. The PFT included measurements of the Forced Expiratory Volume in 1 second (FEV1), Forced Vital Capacity (FVC), FEV1/FVC ratio, Peak Expiratory Flow (PEF), Maximum Expiratory Flows at 75%, 50%, and 25% of FVC (MEF75%, MEF50%, and MEF25%). Spirometry was used to measure the pulmonary function parameters. Each patient underwent spirometry, and the results were recorded and analyzed. The tests were performed according to standard protocols to ensure accuracy and reliability. Any adverse events or changes in the study protocol were promptly reported to the IEC.

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Statistical Analysis

Continuous variables were expressed as medians (interquartile range [IQR]), and categorical variables were presented as numbers and percentages. Chi-squared statistics were employed to evaluate differences between categorical variables. Statistical analyses were performed using SPSS software version 25 (IBM Corp., Illinois Chicago), and a p- value of ≤0.05 was considered statistically significant.

Results

Table 1- Distribution of patients according to baseline variables and past history

Baseline variables		Frequency (n=100)	Percentage
Age (years)	20-30	32	32.0
	31-40	25	25.0
	41-50	28	28.0
	51-60	15	15.0
Gender	Female	45	45.0
	Male	55	55.0
Lung Involvement on Covid Positivity	None	35	35.0
	Mild	33	33.0
	Moderate	21	21.0
	Severe	11	11.0
Requirement of O2 on Covid Positivity	None	36	36.0
	Nasal prong	31	31.0
	Face mask	13	13.0
	NRBM	11	11.0
	NIV	9	9.0
Hospitalization on Covid Positivity	No	36	36.0
	Yes	64	64.0
HRCT grading	No Involvement	35	35.0
	Mild	32	32.0
	Moderate	22	22.0
	Severe	11	11.0

The highest frequency of patients fell within the 20-30 years age group, comprising 32% of the total patients. 55% were male and 45% were female. A majority of the patients (35%) had no initial lung involvement, while 33% had mild involvement, 21% had moderate involvement, and 11% had severe lung involvement. 36% of the patients did not require supplemental oxygen, 31% required a nasal prong, 13% required a face mask, 11% required a non-rebreather mask (NRBM), and 9% required non-invasive ventilation (NIV). A significant majority (64%) of patients required hospitalization. 35% of patients showed no involvement on HRCT, 32% had mild involvement, 22% had moderate involvement, and 11% had severe involvement (Table 1).

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Table 2- Clinical features, findings and outcome at Present visit

Clinical features and findings at present			Frequency (n=100)	Percentage
Symptomatology	Fatigue		56	56.0
	Symptoms that get worse after physical or mental effort		54	54.0
	Fever		3	3.0
	Difficulty in breathing/shortness of breath		34	35.0
	Abnormal Mental Health Condition		1	1.0
	Headache		12	12.0
	Sleep problem		16	16.0
	Depression/anxiety		5	5.0
	Dizziness during stand up		16	16.0
	Chest pain		1	1.0
	Diarrhea/Abdominal pain		0	0.0
General examination	Pulse		75.12±5.330	
	SBP		122.14±10.500	
	DBP		72.66±5.062	
	SPO2		97.89±2.020	
	RR		15.82±1.559	
Spirometry findings		Decreased	56	56.0
		Normal	44	44.0
		Mean±SD	79.39±20.514	
	FEV1 (%)	Decreased	79	79.0
		Normal	21	21.0
		Mean±SD	71.09±19.950	
	FEV1/FVC	Decreased	29	29.0
		Normal	71	71.0
		Mean±SD	77.42±10.508	
	FEF25-75 (%)		54.27±19.725	
	PEFR (%)		67.68±17.571	
Outcome	Normal		24	24.0
	Obstructive		20	20.0
	Restrictive		47	47.0
	Mixed		9	9.0

The most common symptoms were fatigue (56%) and symptoms that worsened after physical or mental effort (54%). The mean pulse rate was 75.12 bpm, and the mean SPO2 was 97.89%. The mean values of FVC (79.39%), FEV1 (71.09%), and FEV1/FVC ratio (77.42%) indicate varying degrees of pulmonary function impairment among the patients. The high percentage of patients with decreased FVC and FEV1 values underscores the commonality of compromised pulmonary function. Restrictive lung disease is the most prevalent condition, affecting nearly half of the patients (47.0%) followed by Obstructive lung diseases (20%) (Table 2).

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Table 3- Comparing mean PFT with baseline variables and past history of COVID

Variables		FVC (%)	FEV1 (%)	FEV1/FVC	FEF25- 75 (%)	PEFR (%)
Age (years)	20-30	82.62±17.8	75.06±17.4	79.86±7.1	60.75±19.1	68.56±13.47
	31-40	81.64±19.0	73.60±17.9	77.77±10.9	56.56±15.6	70.52±17.1
	41-50	78.07±20.2	68.86±18.5	76.63±10.4	52.18±20.8	68.21±18.7
	51-60	71.20±27.5	62.60±28.3	73.15±10.4	40.53±20.8	60.07±18.7
	P value	0.311	0.193	0.223	0.008	0.314
Gender	Female	79.47±19.5	71.89±17.6	77.54±9.7	54.87±18.2	69.64±16.8
	Male	79.33±21.5	70.44±21.8	77.33±11.2	53.78±21.1	66.07±18.2
	P value	0.973	0.719	0.922	0.786	0.314
Initial Lung Involvement on Covid Positivity	None	91.09±21.3	84.11±22.9	79.89±6.8	67.83±17.8	76.34±16.7
	Mild	81.64±9.8	72.33±6.6	78.22±8.1	52.58±14.3	69.45±13.3
	Moderate	71.29±13.7	63.95±8.6	75.18±12.2	48.14±14.2	63.71±12.2
	Severe	34.80±5.4	33.00±5.1	80.58±0.5	27.40±13.3	40.40±15.6
	P value	**<0.001**	**<0.001**	**0.007**	**<0.001**	**<0.001**
Requirement of O2	No	90.61±21.2	83.78±22.7	79.93±6.7	67.56±17.6	76.44±16.4
	Yes	73.08±17.3	63.95±13.9	76.02±11.9	46.8±16.8	62.75±16.3
	P value	**<0.001**	**<0.001**	0.074	**<0.001**	**<0.001**
Requirement of Hospitalization	No	90.61±21.2	83.78±22.7	79.93±6.7	67.56±17.6	76.44±16.4
	Yes	74.71±17.8	64.10±14.7	74.33±12.8	44.87±17.5	61.81±17.3
	P value	**<0.001**	**<0.001**	**0.015**	**<0.001**	**<0.001**
HRCT Grading	No Involvement	91.09±21.3	84.11±22.9	79.89±6.8	67.83±17.8	76.34±16.7
	Mild	82.03±10.2	72.03±6.9	77.64±8.3	51.43±14.5	69.43±13.7
	Moderate	72.62±12.6	64.86±8.7	75.18±12.2	48.38±14.3	64.62±12.8
	Severe	52.60±20.7	40.50±7.4	70.57±19.5	28.5015.6	43.40±15.8
	P value	**<0.001**	**<0.001**	**0.201**	**<0.001**	**<0.001**

There were significant differences in PFT parameters based on age, initial lung involvement, mask requirement, hospitalization requirement, and HRCT grading. Older age groups and those with severe initial lung involvement, oxygen requirement and hospitalization needs showed worse pulmonary function outcomes (Table 3).

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Table 4-Comparing PFT parameters with symptomology

Variables		FVC (%)	FEV1 (%)	FEV1/FVC	FEF25- 75 (%)	PEFR (%)
Fatigue	No	87.48±18.7	79.00±19.8	79.17±7.9	62.89±19.8	73.05±17.5
	Yes	74.87±19.6	66.09±18.3	74.89±12.8	47.53±17.4	63.36±16.4
	P value	**0.001**	**0.001**	0.082	**<0.001**	**0.024**
Symptoms that get worse after physical or mental effort	No	86.78±18.6	78.63±19.5	79.37±7.8	62.80±19.3	72.93±17.2
	Yes	75.79±19.7	66.24±18.5	74.39±13.1	46.36±17.4	63.67±17.3
	P value	**0.001**	**0.001**	**0.044**	**<0.001**	**0.009**
Fever	No	80.39±20.1	72.19±19.5	77.59±10.1	55.21±19.4	68.45±17.1
	Yes	57.0±35.4	35.50±6.4	61.33±28.4	16.0±5.7	32.50±3.5
	P value	0.132	**0.030**	0.132	**0.035**	**0.020**
Difficulty in breathing/ shortness of breath	No	85.17±19.1	76.92±20.4	78.06±9.8	59.43±19.2	71.98±16.9
	Yes	69.63±19.6	59.22±13.6	74.17±12.7	42.26±17.8	57.11±15.8
	P value	**<0.001**	**<0.001**	0.144	**<0.001**	**<0.001**
Mental Health Condition	Abnormal	34.00	32.00	80.32	24.00	36.00
	Normal	80.03±20.2	71.54±19.8	77.26±10.6	54.55±19.8	67.86±17.5
	P value	0.068	0.142	0.665	0.306	0.165
Headache	No	82.41±19.1	74.30±18.7	77.99±8.9	56.92±18.5	70.32±16.0
	Yes	61.45±18.2	50.36±13.8	72.08±19.1	36.27±19.6	49.91±17.5
	P value	**<0.001**	**<0.001**	0.314	**<0.001**	**<0.001**
Sleep problems	No	83.38±18.9	74.84±19.0	77.71±9.4	56.96±19.1	70.10±16.6
	Yes	60.07±19.3	51.60±14.9	74.79±15.5	39.0±18.4	54.8±19.1
	P value	**<0.001**	**<0.001**	0.609	**<0.012**	**0.019**
Depression/ Anxiety	No	81.69±18.7	72.93±18.9	77.05±10.7	55.46±19.4	68.86±16.9
	Yes	39.4±8.4	38.6±10.5	83.21±4.0	31.6±14.4	45.0±16.3
	P value	**<0.001**	**0.001**	0.363	**0.029**	**0.011**
Dizziness during stand up	No	84.46±17.7	74.76±18.9	76.36±11.1	55.72±20.3	69.37±17.5
	Yes	54.14±14.3	52.79±14.0	82.84±2.6	47.36±15.5	60.29±16.4
	P value	**<0.001**	**<0.001**	0.167	0.355	0.184
Chest pain	No	80.02±20.1	71.59±19.7	77.33±10.6	54.56±19.7	67.98±17.5
	Yes	34.00	32.00	80.3200	24.00	36.00
	P value	0.059	0.125	0.785	0.307	0.193

Patients with symptoms such as fatigue, worsening symptoms after effort, fever, headache, sleep difficulties, depression/ anxiety, dizziness and difficulty in breathing had significantly lower PFT parameters, indicating poorer pulmonary function (Table 4).

Discussion

Previous studies revealed that radiological abnormalities continued to exist in majority of patients even months after their discharge. Literature suggests that ground-glass opacities

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(GGO) and interstitial thickness are frequently observed, and there was a strong association between the severity of pneumonia as measured by peak HRCT scores during hospitalization and long-term abnormalities. These findings emphasize the significance of HRCT in tracking the advancement and remission of lung damage after recovering from COVID-19.[10,11] Our findings support the idea that individuals who initially have moderate to severe lung involvement frequently suffer from long-term pulmonary complications. Both studies emphasize the usefulness of HRCT in detecting and measuring the degree of lung injury, which can assist in directing long-term treatment and rehabilitation plans for individuals who have recovered from COVID-19. Continued presence of radiographic abnormalities such as ground-glass opacities (GGOs), reticular patterns, and thickening of the lung tissue between the air sacs suggests continuous inflammation and potential development of fibrosis. This requires extended monitoring and management to minimize long-term respiratory damage. Thus, we conducted this study to assess long term pulmonary involvement in cases following COVID 19 infection.

In our study, prevailing symptoms described by patients were weariness, experienced by 56% of the participants, and symptoms exacerbating following physical or mental exertion, reported by 54% of the participants. Additional symptoms were of dyspnea (35%), cephalalgia (12%), insomnia (16%), and vertigo (16%). These findings are consistent with the wider body of research on long-term COVID-19 symptoms. According to Wu et al.,[10] dyspnea and impaired exercise ability were commonly reported even 12 months after being released from the hospital. Some patients also showed ongoing physiological and radiological abnormalities. Bellan et al.[11] also observed a significant occurrence of diminished lung function and activity limitations four months after discharge, accompanied by a considerable number of patients displaying symptoms of posttraumatic stress. The research conducted by Van den Borst et al.[12] revealed substantial health complications in several areas, such as mental and cognitive impairments, among patients three months following their recovery. This suggests that COVID-19 has a wide-ranging and long-lasting effect on individuals' well-being.

The spirometry results from our study revealed that the mean values for Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), and the FEV1/FVC ratio were 79.39%, 71.09%, and 77.42% respectively. These findings indicate notable declines in lung function following COVID-19. The results are congruent with the study conducted by Patria and Sabirin[13], in which the authors found that the diffusion capacity of carbon monoxide (DLCO) in COVID-19 patients who had recovered was consistently below 80% of the expected value. In severe COVID-19 survivors, researchers observed drastically reduced forced vital capacity (FVC) and total lung capacity (TLC), which suggests the presence of restrictive lung diseases. These findings indicate that COVID-19 has a prolonged detrimental impact on pulmonary function, requiring ongoing surveillance and treatment. Kimmig et al.[14] discovered modest yet enduring decreases in DLCO over a span of 12 months. They saw a significant decrease in maximum exercise capacity, especially in patients who had received intensive care unit (ICU) treatment. However, this decrease did not correspond to the ratings measuring quality of life. In their study, Mo et al.[15] found that a large number of 110 COVID-19 patients who had been

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discharged experienced impairments in their DLCO (diffusing capacity of the lungs for carbon monoxide) and TLC (total lung capacity). Specifically, 47.2% of these patients had aberrant DLCO values. The degree of damage was particularly pronounced in patients with severe pneumonia.

Our study found that a substantial number of COVID-19 survivors experienced notable abnormalities in their pulmonary function tests (PFTs). Specifically, 56% of patients showed a drop in Forced Vital Capacity (FVC), 79% had a decrease in Forced Expiratory Volume in 1 second (FEV1), and 29% had a decrease in the FEV1/FVC ratio. The results align with the extensive health evaluation carried out by Van den Borst et al.[12] which revealed that 42% of patients displayed diminished lung diffusion capacity, whereas 91% exhibited persistent pulmonary abnormalities that were associated with impaired lung function. The study also emphasized the substantial occurrence of mental and cognitive disorders, underscoring the diverse effects of COVID-19 on long-term well-being. In a similar vein, Bellan et al.[11] revealed that over 50% of the patients experienced notable decreases in their lung diffusion capacity, as well as impairment in exercise performance and indications of posttraumatic stress. Patria and Sabirin[13] revealed that individuals who had experienced severe COVID-19 demonstrated a notable decrease in Forced Vital Capacity (FVC) and Total Lung Capacity (TLC). This suggests the presence of restrictive lung diseases. Anastasio et al.[16] observed that individuals who experienced pneumonia during COVID-19 demonstrated decreased resting and exertional SpO2 levels, reduced total lung capacity (TLC), and changed airway occlusion pressure. These findings directly link lung injury during COVID-19 to a subsequent decline in mid-term pulmonary function.

The results of our study indicate that 24% of patients had normal pulmonary function, 20% had obstructive lung disease, 47% had restrictive lung disease, and 9% had mixed patterns of respiratory outcomes. The distribution of data emphasizes the substantial prevalence of restrictive lung diseases among the individuals examined. In a cohort study undertaken by Patria and Sabirin[13] showed a notable decrease in forced vital capacity (FVC) and total lung capacity (TLC). This suggests the presence of restrictive lung illnesses among these survivors. Their findings indicate that COVID-19 could have a prolonged effect on lung function, specifically affecting gas exchange and causing restrictive lung problems. Anastasio et al.[16] found that those who contracted pneumonia during COVID-19 exhibited lower resting and exertion SpO2 levels, decreased total lung capacity (TLC), and changed airway occlusion pressure. This further establishes a connection between lung injury during the acute phase of infection and subsequent mid-term impairments in pulmonary function. Kimmig et al.[14] discovered that although the subjective quality of life scores did not show a correlation with the severity of the initial infection, there was a consistent and slight decrease in DLCO over a period of 12 months. Their study highlights that the decrease in exercise capacity is more likely attributed to deconditioning or tiredness rather than a direct impairment in cardiopulmonary function. These studies jointly demonstrate the significant and enduring respiratory deficits in individuals who have recovered from COVID-19, underscoring the importance of continuous and long-term respiratory care and monitoring.

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There are various limitations in our study that need to be recognized. Initially, the limited sample size may restrict the capacity to apply the findings to larger groups. Furthermore, the study was carried out exclusively at one medical center, which could potentially create biases peculiar to that location. The use of retrospective data collection and reliance on patient self-reporting for symptoms may introduce recollection bias, potentially impacting the accuracy of symptom prevalence. In addition, the subsequent period of observation, albeit thorough, may not fully encompass the complete range of long-term consequences, particularly those that may arise after the observed timeframe.

Conclusions

Our study highlights the significant and multifaceted long-term impacts of COVID-19 on pulmonary function among survivors. A substantial proportion of patients experienced persistent respiratory abnormalities, with restrictive lung disease being particularly prevalent. The necessity for hospitalization and the severity of initial lung involvement were key predictors of long-term pulmonary impairment. Patients who required supplemental oxygen or experienced severe initial lung involvement were more likely to suffer from chronic respiratory issues. The most common long-term symptoms included fatigue, breathlessness, and worsening of symptoms after physical or mental effort, indicating a broad impact on daily functioning and quality of life. Pulmonary function tests revealed significant reductions in FVC, FEV1, FEV1/FVC and DLCO, underscoring the need for ongoing monitoring and rehabilitation. These findings highlights the necessity of comprehensive, long-term care, rehabilitation and follow-up for COVID-19 survivors to manage and mitigate the diverse and persistent sequelae of the COVID-19.

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