ORIGINAL ARTICLE

http://doi.org/10.3126/njr.v15i1.84159

Study of Spirometry and Chest CT Findings in Patients with Moderate to Severe COVID Pneumonia Following Hospital Discharge

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Received: March 26, 2025 **Accepted:** June 10, 2025 **Published:** June 30, 2025

Cite this paper:
Poudyal H, Gurung RB, KC S. Study of Spirometry and Chest CT Findings in Patients with Moderate to Severe COVID Pneumonia Following Hospital Discharge. *Nepalese Journal of Radiology* 2025;15(1):23-31. **http://doi.org/10.3126/njr.v15i1.84159**

ABSTRACT

Introduction: Coronavirus Disease-2019 (COVID-19), the global pandemic, caused by Severe Acute Respiratory Syndrome-Coronavirus-2 (SARS-CoV-2) infection, was first described in Wuhan city of China in December 2019.[1] Diagnosis relies on Reverse Transcriptase polymerase chain reaction (RT-PCR) testing, with high-resolution computed tomography (HRCT) of the chest showing similarities to other viral pneumonias. Post-COVID lung fibrosis can lead to impaired lung function. This study aims to assess pulmonary function in COVID-19 survivors and correlate it with the initial CT severity score on HRCT.

Methods: This study was conducted at Dhulikhel Hospital for a duration of one year among 90 patients with moderate to severe COVID-19 pneumonia. HRCT chest was performed during admission and was categorized using the CT severity score. Spirometry tests were conducted after three months and were compared with the initial HRCT findings.

Results: Among 90 patients, 42(46.7%) were females and 48(53.3 %) were males. The most common spirometry findings in post-COVID-19 patients were a restrictive pattern. Statistically significant correlation was observed between the spirometry findings and initial HRCT findings, suggesting that with increasing degree of CT severity, there was decreased respiratory function during follow-up. Age had a significant correlation with spirometry findings. No association of gender with CT severity score and spirometry was seen in our study.

Conclusions: The result of this study showed that increasing CT severity score could later lead to impairment in pulmonary function. Restrictive lung disease is the predominant lung function impairment in post-COVID-19 pneumonia cases.

Keywords: *COVID-19; Lung; Pandemics; Spirometry*

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INTRODUCTION

As of June 10, 2024, the global COVID-19 pandemic has caused over 775 million confirmed cases and 7.0 million deaths worldwide. The virus, SARS-CoV-2, is highly contagious, and patients commonly present with fever, cough, fatigue, and sometimes respiratory failure. COVID-19 primarily affects the lungs, causing damage to various lung tissues. The severity of the disease can be categorized as mild, moderate, and severe based on clinical and radiological factors.[1,2,3]

HRCT chest is initially used to assess lung involvement and predict outcomes in COVID-19, imaging findings resembling viral pneumonias. However, there is limited data on the significance of chest CT abnormalities in post-COVID-19 survivors. Clinicians need to know if survivors are developing pulmonary fibrosis, which can be assessed by HRCT but comes at a cost of repeated radiation exposure and cost. Thus, basic pulmonary function test such as spirometry is a valuable tool for diagnosis and management of various respiratory disorders. There is limited information on the comparison between follow-up spirometry and initial HRCT findings in our country. This study aims to enhance understanding of HRCT findings and their relationship with spirometry, age, and gender in patients with moderate to severe COVID pneumonia post-hospital discharge. [4,5,6]

METHODS

This prospective study population comprised post-moderate to severe COVID pneumonia patients coming for follow-up in the Department of Internal Medicine of Dhulikhel Hospital and were screened after ethical clearance. A total of 90 patients aged more than 18 years were included. Patients with a history of chronic pulmonary disease, mild COVID pneumonia, suboptimal spirometry/ imaging data, and pregnant women were excluded from the study. We have followed British Thoracic Society (BTS) recommendations for 3 months post-discharge in all post-COVID cases. The assessment of spirometry was conducted in the Department of Internal Medicine using a portable spirometer, SPIROLAB Knudson, as per the standards set by the American Thoracic Society and European Respiratory Society (ATS & ERS), before and fifteen minutes after administration of 400 microgram salbutamol using a pressurized metered-dose inhaler with a small-volume spacer device. Interpretive algorithms were used in determining restrictive or obstructive patterns, and spirometry results were analyzed and categorized into four groups.[7,8]

FEV1: FEV1 is the volume of air exhaled in the first second under force after a maximal inhalation. FVC: FVC is the total volume of air that can be exhaled during a maximal forced expiration effort. FEV1/FVC: The FEV1/FVC ratio is the percentage of the FVC expired in one second. (Table 1)

Table 1: Types of spirometry findings

	FEV1/FVC	FVC
Normal	>70%	> 80% predicted
Obstructive	<70%	> 80% predicted
Mixed	<70%	< 80% predicted
Restrictive	>70%	< 80%

HRCT was performed maintaining appropriate infection prevention and control measures using a single-source Multidetector Computed Tomography (MDCT) scanner, Ingenuity core 128 slice (Siemens, Germany), in a supine position during a single inspiratory breath-hold, from the apex of the lung to the base of the diaphragm. The scanning parameters were KVp=120; mAs=40; rotation time-0.5 second; pitch-1.0; section thickness-5mm; intersection space-5mm. Images were reconstructed at 1 mm slice thickness in all three planes and viewed in the mediastinal (C=60, W=400 and Matrix=512) and lung (C=-600, W=1600 and Matrix=768) windows.

The standard radiological terms were used as described in the standard glossary for thoracic imaging reported by the Fleischner Society. A semi-quantitative CT score was calculated based on the extent of each lobar involvement by an experienced radiologist. The 18 anatomical segments of both lobes of the lung were divided into twenty lung regions. The total CT score would be the sum of the individual lobar scores, ranging from 0 (No involvement) to 25 (Maximum involvement), when all five lobes show more than 75% involvement.[9,10]

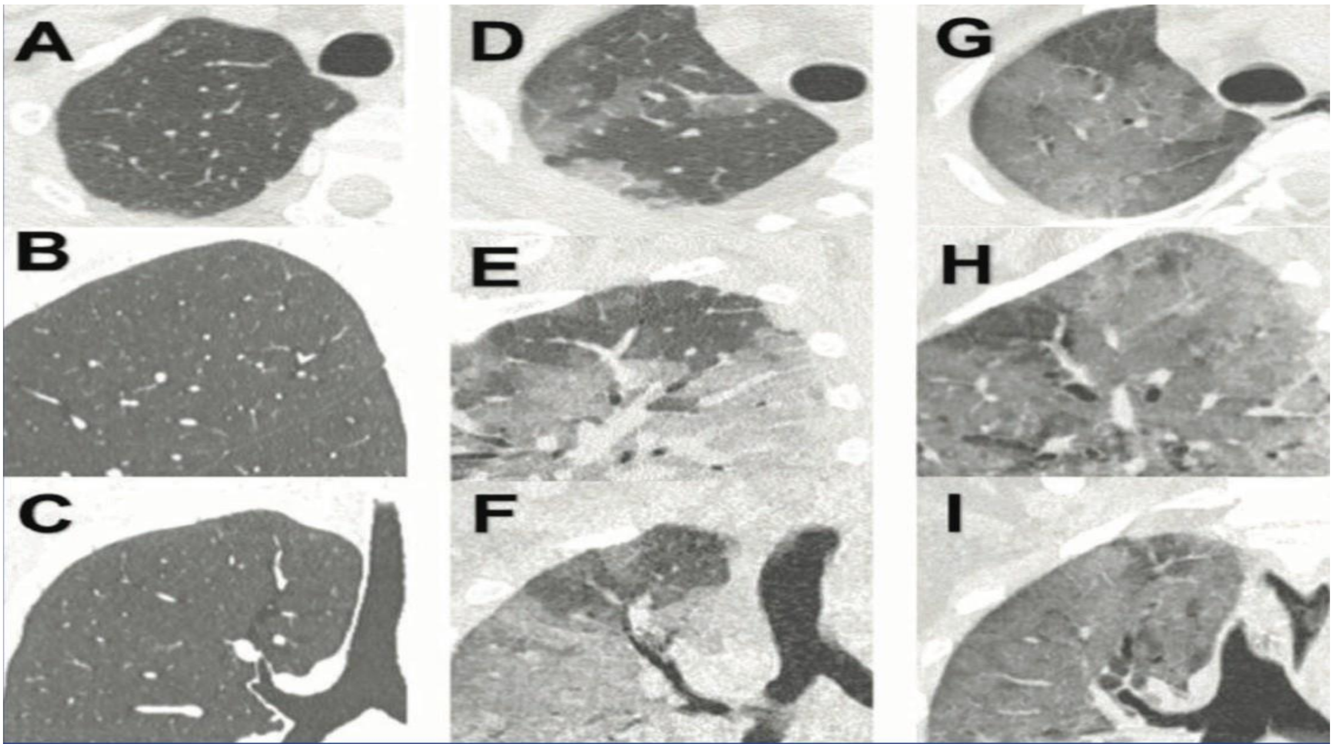
CT SCORE

<5% lung parenchyma involved =1
5-25% lung parenchyma involved =2
25-50% lung parenchyma involved =3
50-75% lung parenchyma involved =4
>75% lung parenchyma involved =5

A CT Severity score <8 is considered to be Mild involvement.

CT Severity score 8-15 is considered to be Moderate involvement.

A CT Severity score >15 is considered to be Severe involvement.



[Table/Fig-2]: CT severity scoring pattern in apical region of right upper lobe in different RT-PCR positive COVID-19 patients; A, B, C) No lung involvement in 54-year-old male, implies CT score zero; D, E, F) Less than 50% involvement of apical segment of right upper lobe in 48-year-old female, implies CT score one; G, H, I) More than 50% involvement of apical segment of right upper lobe in 45 years, implies CT score two.

Figure 1: *CT severity pattern in the apical segment of the right upper lobe in different RT-PCR COVID-19 patients; A, B, C)No involvement implies a CT score of zero, D, E, F)less than 50% involvement implies a CT score of 2; G, H, I) more than 50% involvement implies a score of 2.*[10]

Data entry and analysis were done with the help of a computer using the SPSS software program 20. In this study, statistical analysis was done by relevant statistical tests, including frequency and percentage. Differences in gender and age group were assessed using the chi-squared test of significance. In all of the above tests, a p-value of less than 0.05 was accepted as statistically significant.

RESULTS

During the study period, 90 patients fulfilling the criteria were enrolled in the study. Among them, 42(46.7%) were females and 48(53.3%) were males. Age ranged from 19 to 81 years, and the mean age was 49 years. The majority were in the age group of 40-60 years.

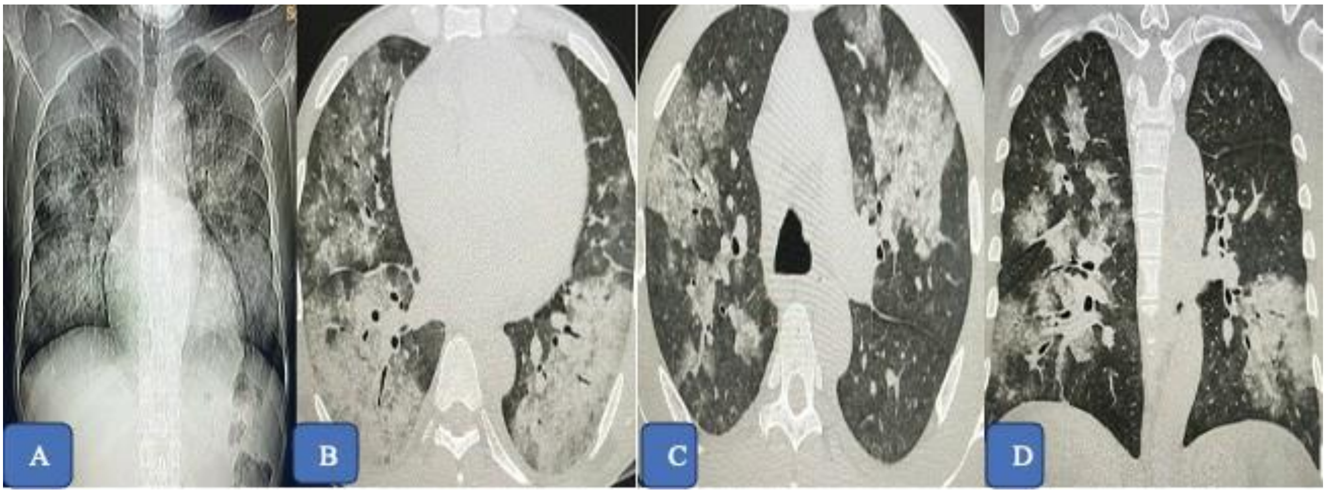


Figure 2: *A. scout images showing extensive bilateral pneumonia involving all lobes. B, C, D showing multifocal peripheral and bibasal extensive consolidation and bronchial wall dilatation*

All patients with moderate to severe COVID pneumonia had consolidation and ground glass opacities(100% (n=90). Reticular pattern was observed in 75.6% (n=68), Bronchial dilatation in 94.4% (n=85), and architectural destruction in 68% (n=54). Cavitations were not observed in HRCT of any of the patients, whereas pleural effusion was observed in 95.6% (n=86) of patients. Bibasal, asymmetrical, peripheral, and multifocal subpleural distribution of opacities was the hallmark feature. Based upon all these HRCT parameters, patients were assigned a CT severity score of moderate involvement in 93.3% (n=84) and 6.7% (n=6) as severe involvement. There was no observed correlation between the CT severity score with age group and gender, as shown in Table 2 (p-value > 0.05).

Table 2: CT severity score in different age groups and gender

Study Variables		CT Severity score Total (n)=90(100%)		P-value
		Moderate	Severe	
Age group	**19-39 years**	22(24.44%)	2(2.22%)	0.1
	40-60 years	44(48.88%)	3(3.33%)	
	61-81 years	18(20%)	1(1.11%)	
		84(93.3%)	6(6.67%)	
Gender	**Male**	44(48.88%)	4(4.44%)	0.45
	Female	40(44.44%)	2(2.22%)	
		84(93.3%)	6(6.67%)	

The mean FEV1 values for patients with moderate to severe disease were 1.81 and 1.41, respectively, as shown in Table 3. Similarly, in patients with moderate and severe disease, the mean FVC values were 2.26 and 1.71, respectively. The FEV1/FVC ratio for patients with moderate to severe disease was 78.79 and 83.53, respectively. It was worth noting that both the FEV1 and FVC values were significantly lower in patients with severe disease (1.41 and 1.71, respectively) compared to those with moderate disease (1.81 and 2.26, respectively) (p-value < 0.05). Additionally, the mean FEV1/FVC ratio in patients with severe disease (83.53) was higher than in those with moderate disease (78.79), but this difference did not reach statistical significance (p value of 0.7).

A negative association was observed between CT severity and FVC and FEV1. As CT severity increased, there was a declining pattern in FVC and FEV1. Additionally, a very weak positive association was observed between the FEV1/FVC ratio and CT severity score, where as the CT severity increased, the FEV1/FVC ratio also increased.

Table 3: Mean values of FEV1, FVC, and their ratio in Moderate to Severe COVID pneumonia cases

CT severity score		Spirometry findings		
		FEV1	FVC	FEV1/FVC
Moderate(n=84)	Mean	1.81	2.26	78.79
Severe(n=6)	Mean	1.41	1.71	83.53
P-value		0.02	0.01	0.70

The majority of patients (60%; n=54) had normal spirometry findings on follow-up; followed by restrictive pattern (21.1%; n=19), mixed(obstructive and restrictive pattern) (6.67%; n=6), and obstructive pattern (12.22%; n=11) as shown in table no. 4. The majority of normal spirometry findings were found in the age group of 19-60 years, while the mixed patterns were equally seen in the both age group of 40-60 years and 61-81 years, in contrast to the restrictive pattern which was notably higher in the age group of 40-60 years (n=15, 16.67%). Age had a statistically significant correlation with spirometry findings (p-value < 0.05). There was no notable correlation found between gender and spirometry findings (p-value> 0.05). Nevertheless, male patients exhibited a higher prevalence of restrictive pattern compared to females. The mixed pattern was equally observed in both genders.

Table 4: Spirometry findings in different age groups and gender

Study Variables		Spirometry findings					P value
		Normal	Obstruction	Mixed	Restriction	Total N(%)	
Age group in years	19-39	22(24.4%)	1(1.11%)	0	1(1.11%)	24(26.7%)	<0.05
	40-60	26(28.8%)	3(3.33%)	3(3.33%)	15(16.67%)	47(52.2%)	
	61-81	6(6.66%)	7(7.77%)	3(3.33%)	3(3.34%)	19(21.1%)	
Total		54(60%)	11(12.2%)	6(6.66%)	19(21.1%)	90(100%)	
Gender	**Male**	26(28.8%)	6(6.66%)	3(3.31%)	13(14.44%)	48(53.33%)	0.79
	Female	28(31.1%)	5(5.55%)	3(3.31%)	7(7.77%)	42(46.77%)	
Total		54(60%)	11(12.22%)	6(6.66%)	19(21.11%)	90(100%)	

A significant correlation was observed between the spirometry and CT severity score, as shown in Table 5. Out of 6 patients with severe CT severity score, the majority exhibited a restrictive pattern 4(66.66%). Similarly, among 84 patients with a moderate CT severity score, the majority had normal spirometry findings 53, 63.09%), followed by a restrictive pattern in 15(17.85%), an obstructive pattern in 10(11.9%), and mixed patterns in 6(7.14%).

Table 5: Spirometry and CT severity score

Spirometry findings	CT severity score		Total	P value
	Moderate	Severe		
Normal	53(63.09%)	1(16.66%)	54(60%)	0.03
Obstruction	10(11.91%)	1(16.66%)	11(12.2%)	
Mixed	6(7.14%)	0	6(6.67%)	
Restriction	15(17.85%)	4(66.66%)	19(21.12%)	
Total	84	6	90	

DISCUSSION

Our study showed a significant number of infections among individuals aged 40-60 years, amounting to 47 cases (52.22%), in line with the prevailing disease trend in Nepal. Males showed a slightly higher rate of infection(53.33%) in our study, in accordance with worldwide data. Similar gender predominance was also seen in a study done by Shahi et al. among 120 patients, where 75% were males, and the mean age was 54.70 ± 15.56 years. This age group involvement is in line with several previous studies, ranging from 46 to 54 years.13 However, Li et al. don't document age group affection in their study. A study done by Liu et al. showed that the majority of patients were in the higher age group of 69.1 ±7.8 years.[11,12,13]

In our study, a higher CT severity score in COVID-19 patients was seen in males compared to females, which is similar to the findings of Sharma et al. and Saeed et al. However, there was no significant association between the age group and CT severity score in our study, which was similar to the study by Sharma et al. In contrast, a study done by Saeed et al. showed a higher CT severity score in the age group of 50 to 59 years. HRCT by Sharma et al. showed pure ground glass opacities in 99(90.5%), consolidation in 66(63.2 %), and vascular dilatations in 73(70.2%). A study by Ai T et al. showed 3% of RT-PCR positive cases showing normal HRCT results despite having clinical symptoms. Bao et al. meta-analysis revealed a pooled positive rate of 89.7% for HRCT chest scans. This suggests the possibility of a divergent course of the disease in different populations and timing of the HRCT chest.[14,15,16,17]

Shah et al.'s study showed that only 52.7% of COVID-19 patients had normal HRCT scans. This contradicts previous studies by Yiecheng F et al. that recommended using HRCT as a screening tool due to its high sensitivity. However, the American College of Radiology (ACR) advises against using HRCT as the primary diagnostic method and emphasizes the importance of RT-PCR testing. Our study had a higher prevalence of abnormal CT scans, possibly due to conducting CT scans on all symptomatic RT-PCR positive patients.[18,19,20]

COVID-19 pneumonia follows a temporal course where peripherally placed GGOs are followed by consolidations and a crazy paving pattern, as shown in the study by Pan et al. The predominant imaging findings in our study included bibasal, peripheral, GGOs with consolidation, a classical hallmark of COVID-19. The majority of our study population had pleural effusion (95.6%, n=86), which could be due to extensive pneumonia, in contrast to other studies where pleural effusion was uncommon. A study done by Sharma et al. showed pleural effusion in 13.5% cases only.[14,21]

Normal spirometry was obtained in 60% of patients (n=54) in our study; rest showing abnormal spirometry pattern of restrictive (21%, n=19) followed by obstructive (12.22%, n=11) and mixed pattern in 6.67% (n=6), which was similar to the study conducted by Xiaoneng Mo et al. A study done by Shital et al. showed higher abnormal spirometry seen in 77.5% cases; restrictive pattern was the predominant type (43.33%) followed by normal lung functions in 22.5% cases. A similar finding was observed in a study done by Patra et al., which showed 33%

had mild, 22% had moderate, and 4% had severe lung disease, while 41% showed normal findings on spirometry.[22,23,24]

Shital et al.'s study revealed a statistically significant association between age and gender with spirometry. Our study also showed age had a statistically significant correlation with spirometry findings (p-value<0.05). However, there was no notable correlation found between gender and spirometry findings (p-value>0.05).[23]

Patra et al.'s study showed patients with severe lung disease on HRCT had lower mean values of FEV1 and FVC as compared to mild and moderate disease (both p values<0.05), similar to our study. Additionally, the mean FEV1/FVC ratio was lower in patients with severe disease (97.81±24.02) compared to moderate disease (101.03±14.66), although this difference was not statistically significant (p value of 0.665). Guler SA et al. found similar findings to our study, showing lower lung volumes (TLC, FVC, and FEV1) and a higher FEV1/FVC ratio, suggesting a restrictive pattern, indicating the issue lies in the lung parenchyma.[24,25]

Salem et al. in their study documented findings of restrictive lung impairment in about 50% of cases, which is in line with several previous studies ranging from 10-50%.[26,13] Similarly, in our study, among the abnormal spirometry, a restrictive pattern was seen in 21% and an obstructive pattern in 12.22% cases. A systematic review by R. Torres-Castro et al. showed a restrictive pattern and an obstructive pattern in 15% and 7% of patients, respectively.[13] These disparities in the prevalence of restrictive lung defect might be explained by the timing of evaluation, which ranged from close to discharge to three months after discharge.

Wan et al. have found a link between disease severity and decreased lung function. Studies suggest that COVID-19 survivors may have fibrotic-like changes on CT scans, but it is unclear if these changes indicate permanent fibrosis. Further research is needed to understand these changes. Use of noninvasive mechanical ventilation, like in our study population, during hospital stay can lead to ventilator-induced lung injury, which is a risk factor for fibrotic-like changes. This aligns with previous research showing a strong link between mechanical ventilation and fibrotic-like changes in moderate to severe COVID pneumonia. [26,27,28]

A higher CT severity score of 18 was independently associated with fibrotic-like changes at the 6-month follow-up. Previous studies have linked CT scores to pulmonary fibrosis and mortality in COVID-19 patients. Therefore, a greater extent of lung injury in the acute phase may be associated with fibrotic-like changes, which was also confirmed in spirometry in our study.[28]

CONCLUSION

Abnormal spirometry was found in 40% of COVID-19 survivors, with both restrictive and obstructive findings. Using spirometry and CT Severity score, we can improve patient outcomes, with CT imaging guiding immediate treatment and spirometry evaluating long-term lung function for decisions on pulmonary rehabilitation.

CONFLICT OF INTEREST

None

SOURCES OF FUNDING

None

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