

# Association of the Severity of Emphysema Based on HRCT Scoring System with Clinical Profile and Pulmonary Function Test Parameters: A Cross-sectional Study

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## ABSTRACT

**Introduction:** Chronic Obstructive Pulmonary Disease (COPD) is commonly observed in middle aged and elderly individuals. Dyspnoea, with or without expectoration, or isolated dyspnoea, is the primary respiratory symptom. Clinical signs, symptoms, and Pulmonary Function Tests (PFTs) are non specific. Chest radiography poorly correlates with disease severity and extent compared to clinical and functional impairment. High-Resolution Computed Tomography (HRCT) has been widely adopted to detect, characterise, and quantify emphysema. HRCT scoring is a useful radiological method for assessing emphysema severity in COPD patients and can provide prognostic information.

**Aim:** To assess the severity of emphysema based on the HRCT scoring system and its association with clinical profile and PFTs.

**Materials and Methods:** The present cross-sectional observational study was conducted in the Department of Radiodiagnosis at Atal Bihari Vajpayee Institute of Medical Sciences and Ram Manohar Lohia Hospital, New Delhi, India. It included 30 clinically diagnosed COPD patients referred for HRCT lung scans from November

1,2018, to March 31, 2020. HRCT assessment was performed at three levels: carina, 5 cm above carina, and 5 cm below carina. The severity of lung parenchyma was evaluated using the "Sakai Scoring Method." The emphysema score was correlated with clinical profile (duration of illness, COPD severity, smoking, and pack-years smoked) and PFT parameters (FEV<sub>1</sub>, FEV<sub>1</sub>/FVC).

**Results:** The mean age of the cases was 60±9.44 years. There was a strong positive linear correlation between the duration of illness ( $r=0.67$ ,  $p=0.001$ ) and COPD severity ( $r=0.452$ ,  $p=0.02$ ) with HRCT emphysema score. Significant correlation was found between HRCT emphysema score and pack-years smoked ( $r=0.558$ ,  $p=0.004$ ). The emphysema score showed an inverse correlation with FEV<sub>1</sub> ( $r=-0.56$ ,  $p=0.002$ ) but no correlation with Forced Expiratory Volume 1/Forced Vital Capacity (FEV<sub>1</sub>/FVC) ( $r=-0.16$ ,  $p=0.430$ ).

**Conclusion:** The HRCT semi-quantitative scoring system is valuable for the initial assessment of disease severity and is significantly correlated with the PFT parameter FEV<sub>1</sub>.

**Keywords:** Carina, Chronic obstructive pulmonary disease, Dyspnoea, High resolution computed tomography

## INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD), described by the Global Initiative for Obstructive Lung Disease (GOLD), is a disease characterised by irreversible airway obstruction and ranks 5<sup>th</sup> in global disease burden according to the World Health Organisation (WHO) [1,2]. COPD encompasses several overlapping obstructive syndromes, including emphysema, chronic bronchitis, and small airway disease [3,4]. Airflow obstruction in COPD can result from lung parenchymal destruction (emphysema), airway narrowing, or both factors. Emphysema is a progressive disease that leads to breathlessness, chronic cough, sputum production, and systemic effects. Lung function decline occurs due to emphysema and small airway narrowing, resulting in air trapping, progressive airflow limitation, and exertional dyspnoea. The Medical Research Council (MRC) dyspnoea scale is a valid tool for measuring dyspnoea and assessing functional status and severity [5].

Impaired lung function growth during early years and adolescence, caused by factors such as infection, allergens, tobacco smoking, and genetic susceptibility, increases the risk of COPD [6,7]. Tobacco smoking is a significant risk factor for COPD, with longitudinal studies showing a dose-response relationship between smoking intensity (in pack-years) and FEV<sub>1</sub> decline [8]. However, approximately 10% of clinically diagnosed COPD cases globally are non smokers, a proportion that is higher in Indian women due to biomass fuel exposure [8]. COPD is now recognised to have systemic consequences beyond the lungs. Spirometry, a

common tool for assessing airway obstruction, allows for a simple, repeatable, non invasive, and cost effective global assessment of functional changes. Parameters such as FVC, FRC, and FEV<sub>1</sub> are used. COPD is diagnosed when the FEV<sub>1</sub>/FVC ratio is lower than 70% [9], but this does not provide information about the underlying pathology or the distribution of emphysema [10,11].

Pulmonary Function Tests (PFTs) offer a convenient means of screening and assessing the progression of lung disease [12]. However, FEV<sub>1</sub> alone cannot capture the heterogeneity of the disease. Peak oxygen uptake (Peak VO<sub>2</sub>) from cardiopulmonary exercise testing and the distance walked during the six Minute Walk Test (MWT) are employed to assess response to therapeutic interventions and track disease progression [13]. Chest radiography lacks specificity for different COPD types, providing non specific findings. HRCT overcomes the limitations of chest radiography and offers more detailed information [14].

The HRCT permits detailed anatomical examination of pulmonary structure and is widely used to detect, characterise, and quantify emphysema. It has been used to categorise COPD patients into two main groups: those with emphysema-predominant disease and those with airway-predominant disease [15]. Differentiation between these two groups is important because the management strategies differ i.e., lung volume reduction surgery may be effective for patients with emphysema-predominant COPD, while medical treatment is more appropriate for those with airway-predominant COPD [16].

Several studies have shown that CT is valuable in quantifying disease severity in COPD, using visual or quantitative CT techniques [17,18]. HRCT provides information about the severity and extent of the disease process and can be quantified using a numerical score [19,20]. Qualitative assessment of emphysematous changes correlates well with airflow obstruction, while objective measures of airway wall thickening also correlate with pulmonary function [21-24]. A higher CT-emphysema score is associated with a poor prognosis in patients with advanced squamous cell lung cancer, and higher mortality from pneumonia is observed in patients with a higher CT-emphysema score [25].

There is limited research on HRCT scores for assessing the severity of emphysema in COPD in the Indian setting. Therefore, present study was undertaken to assess the severity of emphysema using HRCT scoring and to examine the correlation between HRCT scores, non invasive PFTs (FEV1 and FEV1/FVC), and clinical profile.

## MATERIALS AND METHODS

The present cross-sectional observational study was conducted in the Department of Radiodiagnosis at Atal Bihari Vajpayee Institute of Medical Sciences and Dr. Ram Manohar Lohia Hospital, New Delhi, India. from November 1, 2018, to March 31, 2020. The study received approval from the institutional Ethics Committee (no.TP(MD/MS)(80/2018)/IEC/PGIMER/RMLH/913). A total of 30 patients with a clinical diagnosis of COPD were included in the study.

**Sample size calculation:** The sample size was calculated using the formula  $N = \{(Z\alpha + Z\beta)/C\}^2 + 3$ , where  $Z\alpha$  represents the standard normal deviate for  $\alpha$  (1.96),  $Z\beta$  represents the standard normal deviate for  $\beta$  (0.842), and  $C$  represents  $0.5 * \{(1+r)(1-r)\}$ . The calculated sample size was 29.02.

**Inclusion criteria:** Patients of any age and sex who presented with dyspnoea, were referred for HRCT scan of the chest, met the clinical severity criteria for COPD according to GOLD, and were willing to undergo HRCT, were included.

**Exclusion criteria:** Patients with acute exacerbation of COPD were excluded from the study.

### Study Procedure

The severity of dyspnoea was graded from 1 to 5 according to the MRC dyspnoea scale [Table/Fig-1]. A thorough clinical history was taken, including symptoms such as dyspnoea, cough with or without expectoration, fever, malaise, chest pain, and smoking. The duration of clinical symptoms and smoking history were also recorded.

Grade	Severity of dyspnoea
1	Not troubled by breathlessness except on strenuous exercise
2	Short of breath when hurrying on the level or walking up a slight hill
3	Walks slower than most people on the level, stops after a mile or so, or stops after 15 minutes walking at own pace
4	Stops for breath after walking about 100 yards or after few minutes on level ground
5	Too breathless to leave the house, or breathless when undressing

**[Table/Fig-1]:** Clinical severity of dyspnoea as per MRC breathlessness scale.

Pulmonary function test (PFT) reports, including FVC, Functional Residual Capacity (FRC), and FEV1, were collected from records or the respiratory laboratory. The GOLD system was used to categorise patients into mild (GOLD 1), moderate (GOLD II), severe (GOLD III), and very severe (GOLD IV) airflow limitation categories based on PFT findings. Chest X-rays were studied for the presence of any radiological abnormalities. HRCT of the chest was performed for all cases. The procedure and objectives of the HRCT scan were explained to the patients, and written consent was obtained. The

patients were instructed on breath-holding during the acquisition of scans. The scans were acquired in the supine position, in the cephalocaudal direction from the apex to the base in axial planes. A 128-slice Computed Tomography (CT) scanner (Siemens "Somatom Definition Flash") was used with the following acquisition protocol: collimation=1 mm, feed=10 mm, kVp=120-140, mA=240, matrix size=512x512, scan time=1 sec, and window level (mean)/width values=-600 to -700/1000 to 1500.

After image acquisition, the HRCT scan was assessed at three levels: the level of the carina, 5 cm above the carina, and 5 cm below the carina. The lung parenchyma was graded and scored separately for both the left and right lungs, resulting in a total of six lung fields. The severity score of lung parenchyma was assessed using the Sakai Scoring Method, as explained in [Table/Fig-2]. The final emphysema score for each lung field was calculated as Severity x Extent. The sum of the total emphysema scores in both lung fields ranged from 0 to 72 (considering a maximum grade of 3 and a maximum score of 4 for six lung fields).

Severity	Extent
Grade 0: No emphysema	Score 1: 25 % lung field involvement
Grade-1: Low HRCT attenuation areas <5 mm in diameter with or without vascular pruning	Score 2: 25-50% lung field involvement
Grade 2: Circumscribed low HRCT attenuation >5 mm in diameter + <5 mm in diameter with vascular pruning but with normal lung intervening	Score 3: 50-75% lung field involvement
Grade 3: Diffuse low attenuation areas without normal lung intervening or Confluent large attenuation areas with vascular pruning and distortion of lung branching pattern occupying all or almost all of lung	Score 4: 75-100% lung field involvement

**[Table/Fig-2]:** Lung parenchyma severity score (Sakai scoring method).

Statistical analysis was used to correlate the HRCT emphysema scoring (dependent variable) with clinical parameters (duration of illness, COPD severity, smoking, number of pack-years smoked) and PFT parameters (FEV1, FEV1/FVC). The outcomes studied included lobar emphysema distribution and emphysema score, gender association with pack-years smoked, PFT, and HRCT emphysema score, PFT and HRCT score parameters, and HRCT emphysema score versus clinical features (dyspnoea).

## STATISTICAL ANALYSIS

The statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 22.0. Categorical variables were presented as numbers and percentages (%), while continuous variables were presented as mean±Standard Deviation (SD). Student's t-test and one-way Analysis of Variance (ANOVA) followed by a post-hoc test (Tukey's) were used to compare quantitative variables. Chi-square or Fisher's-exact test was used to compare qualitative variables. A p-value <0.05 was considered statistically significant.

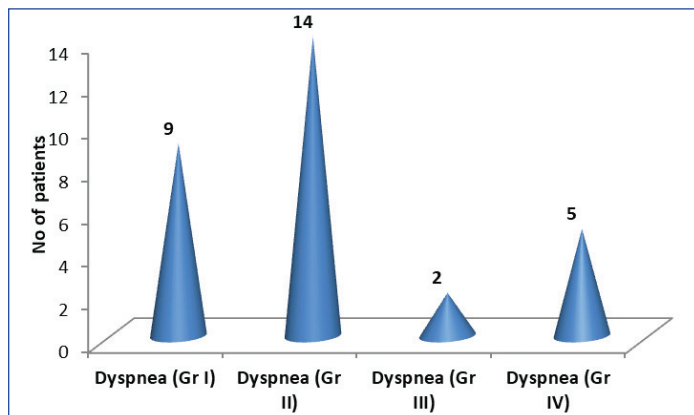
## RESULTS

The mean age of the cases was 60±9.44 years (range: 42-80 years). The study included 21 (70%) male and 9 (30%) female patients. The average duration of COPD was two years (ranging from 1 month to 7 years). Dyspnoea was the main presenting symptom in all patients, with other reported symptoms including chronic cough (26%), cough with expectoration (23%), fever (13%), and wheezing (10%). Malaise and chest pain in 6.6% of patients. Among the 30 study patients, 46.7% were current smokers, 20% had a history of smoking cessation, 23.3% were non smokers, and 10% were occasional smokers.

Physical examination revealed tobacco staining on teeth in 20% of patients, while clubbing of nails, barrel-shaped chest, and hepatomegaly

were noted in 6.6% patients. Cervical lymphadenopathy was observed in 3.3% of patients.

The majority of patients (76.7%) in present study were in dyspnoea Grade I and Grade II according to the MRC breathlessness scale [Table/Fig-3]. However, according to the GOLD classification, which is based on FEV1 and FEV1/FVC, 27 patients were analysed as 3 patients could not perform PFT. The majority of patients (63.33%) were in the moderate and severe stages [Table/Fig-4].



[Table/Fig-3]: Patients with clinical severity dyspnoea grades (MRC).

Gold stage	Number of cases	Percentage (%)
Stage I (mild)	3	10.0
Stage II (moderate)	9	30.0
Stage III (severe)	10	33.3
Stage IV (very severe)	5	16.7

[Table/Fig-4]: GOLD stages of COPD.

\*GOLD: Global initiative for chronic obstructive lung disease

No abnormality was seen on chest X-ray in 14 (46.7%) patients. Hyperinflated lung was seen in 4 (13.3%), whereas fibrotic opacities were noted in 3 (10%) patients [Table/Fig-5].

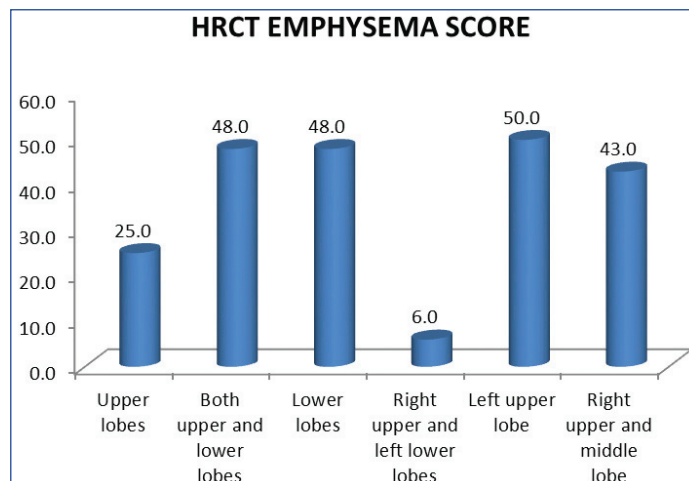
Chest X-ray finding	N (30)	N%
Right upper zone consolidation	1	3.3
Hazy opacity in right horizontal fissure	1	3.3
NAD (No abnormality)	14	46.7
Fibrobronchiectatic changes	1	3.3
Fibrotic opacities	3	10
Hyperinflated lung with fibrotic opacities in right lower lobe	1	3.3
Fibronodular opacities with consolidation	1	3.3
Hyperinflated lung	4	13.3
Hyperinflated lung with fibrotic opacities	1	3.3
Hyperinflated lung, left pleural effusion	1	3.3
Prominent bronchovascular markings	1	3.3
Prominent bronchovascular markings, blunting of CP angle	1	3.3
Total	30	100

[Table/Fig-5]: Chest X-ray findings.

Chest X-rays showed no abnormality in 46.7% of patients, hyperinflated lungs in 13.3% of patients, and fibrotic opacities in 10% of patients.

Upper lobe predominance of emphysema was observed in 70% of patients. The mean HRCT score was 25 in patients with upper lobe predominance, while patients with both upper and lower lobe involvement had a mean score of 48 [Table/Fig-6]. FEV1/FVC scores ranged from 47 to 79, with an average of 67 points. FEV1 scores ranged from 23 to 90, with an average of 49 points [Table/Fig-7]. The HRCT scores of clinical cases showed various types and distributions of emphysema, with corresponding total scores indicating the severity of lung changes [Table/Fig-8-14]. There was

a significant difference in FEV1 scores between male and female patients, with male patients being more severely affected (average of 44.4±17 points) compared to female patients (average of 60.75±16.47 points) [Table/Fig-15].



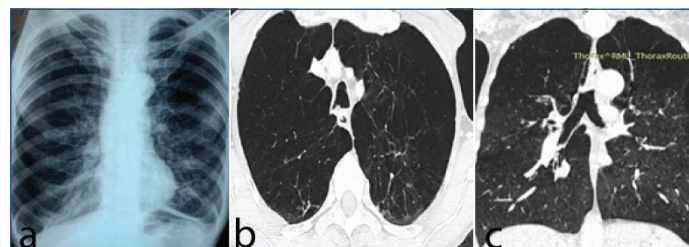
[Table/Fig-6]: Lobar distribution and mean emphysema score.

Parameters	N	Minimum	Maximum	Mean±SD
FEV1/FVC (%)	27	47.0	79.0	67.519±8.8028
FEV1 (%)	27	23.0	90.0	49.296±18.6688
HRCT emphysema score (Sakai scoring method)	30	6.0	61.0	30.433±18.6227

[Table/Fig-7]: Pulmonary Function Test (PFT) and HRCT score parameters.



[Table/Fig-8]: Case 1; A 60-year-old female patient, a case of COPD presented with fever and dyspnoea. HRCT axial image of bilateral upper lobes, 5cm above the carina shows centrilobular and paraseptal emphysema with subpleural bulla formation. A total score of 11 was estimated on HRCT (9 on right and 2 on left).

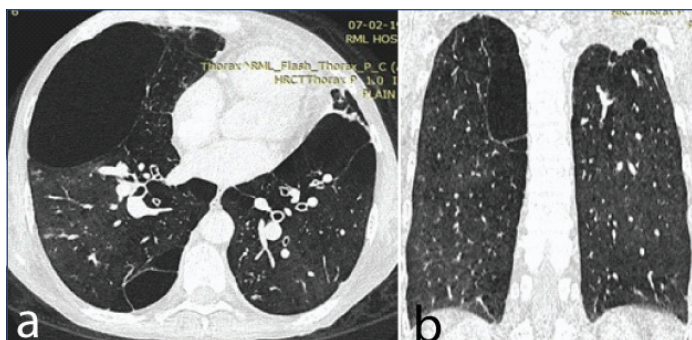


[Table/Fig-9a-c]: Case 2; A 60-year-old patient of COPD with chronic smoking history and dyspnoea. Chest X-ray (a) shows hyperinflation of both lung fields. Axial HRCT image (b) shows diffuse panacinar emphysema in bilateral upper lobes. HRCT score taken at 5cm above carina is 12 on either side with a total of 24. Coronal image (c) shows the predominant involvement of bilateral upper lobes.

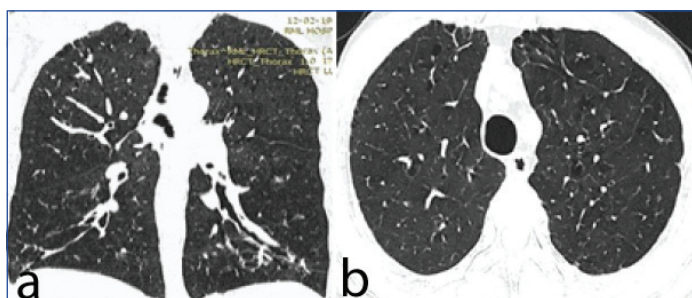
Smoking history and HRCT score showed a strong positive correlation, indicating that as smoking history increases, the HRCT score also increases ( $r=0.500$ ,  $p=0.011$ ). There was also a strong positive linear correlation between the duration of disease and HRCT score ( $r=0.67$ ,  $p=0.001$ ) [Table/Fig-16].

The mean HRCT emphysema score in all patients was 30.43±18, with higher scores observed in patients with more advanced

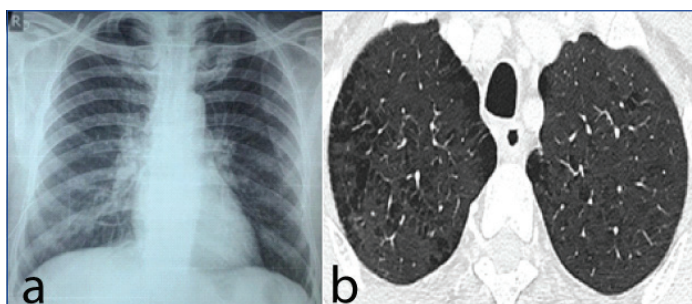




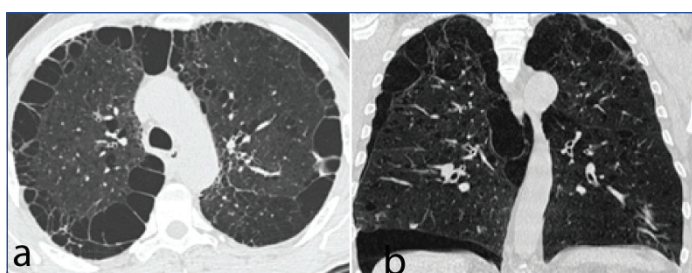
**[Table/Fig-10a-b]:** Case 3: A 45-year-old COPD patient with shortness of breath. HRCT axial (a) and coronal (b) images show paraseptal emphysematous changes in subpleural location. Axial scan shows bullous transformation of emphysema. HRCT score taken 5 cm below carina, measures 9 and 4 on right and left-side, respectively.



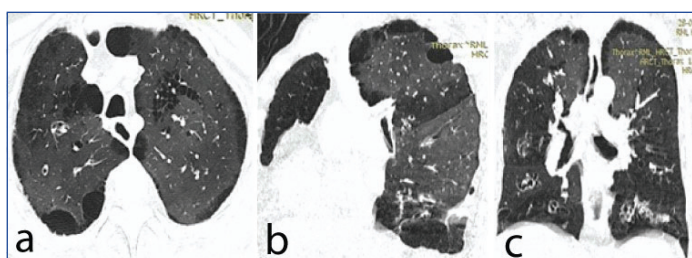
**[Table/Fig-11a-b]:** Case 4: A 60-year-old man with smoking history and dyspnoea. HRCT axial (a) and Coronal (b) images show centrilobular emphysema in upper lobes. HRCT score, 5 cm above carina is 2 on both sides with a total of 4.



**[Table/Fig-12a-b]:** Case 5: A 54-year-old COPD patient with breathlessness. Chest X-ray (a) reveals no abnormality. HRCT axial (b) scan at 5cm above carina shows paraseptal and centrilobular emphysema. HRCT score is 6 and 2 on right and left-side, respectively with a total score of 8.



**[Table/Fig-13a-b]:** Case 6: A 55-year-old male patient with chronic smoking history and dyspnoea. HRCT axial (a) and coronal (b) images show paraseptal emphysematous changes in peripheral distribution. HRCT score, 5cm above carina measures 12 on right side and 9 on left-side, with a total of 21.



**[Table/Fig-14a-c]:** Case 7: A 60-year-old COPD patient with history of chronic smoking. HRCT axial (a), sagittal (b) and coronal (c) images show centrilobular and paraseptal emphysematous changes. HRCT score, 5 cm above carina is 4 and 2 on right and left side, respectively, giving a total of 6. The total score of the entire lung field was 10.

Gender association		N	Mean	T-value	p-value
Smoking, pack-year	Male	19	31.2±15.3	1.302	0.207
	Female	4	19±24.9		
FEV1/FVC (%)	Male	19	65.6±9.63	-1.732	0.096
	Female	8	71.8±4.25		
FEV1 (%)	Male	19	44.4±17.7	-2.219	0.036
	Female	8	60.75±16.47		
HRCT emphysema score	Male	21	33.2±18.45	1.302	0.212
	Female	9	23.7±18.28		

**[Table/Fig-15]:** Gender association with pack-years smoked\*, PFT and HRCT emphysema score.  
\*pack-year smoked is calculated by multiplying the number of packs of cigarettes smoked/day by the number of years the person has smoked

HRCT emphysema score correlation	No. of cases	r	p-value
Age (years)	30	0.232	0.217
FEV1/FVC	27	-0.16	0.430
FEV1	27	-0.56	0.002
Duration of disease	21	0.67	0.001
Smoking history	21	0.500	0.011
Smoking pack year	21	0.558	0.004
GOLD stage severity	21	0.452	0.02

**[Table/Fig-16]:** Correlation of clinical and PFT with HRCT emphysema score.

stages of COPD based on GOLD classification (37.2±23.5 in COPD GOLD stage 4, 40.4±13.7 in COPD GOLD stage 3, p<0.01) [Table/Fig-17].

There was a statistically significant difference in the mean scores of HRCT emphysema among patients with different grades of dyspnoea (p=0.001) [Table/Fig-18].

Disease severity (as per GOLD stage)	No. of cases	HRCT emphysema score (Mean)	SD	95% Confidence interval for mean		F-value	p-value
				Lower bound	Upper bound		
Mild (Stage 1)	3	8.0	2.0000	3.032	12.968	4.715	0.01
Moderate (Stage 2)	9	21.4	14.4491	10.338	32.551		
Severe (Stage 3)	10	40.4	13.7857	30.538	50.262		
Very severe (Stage 4)	5	37.2	23.5733	7.930	66.470		
Total	27	29.9	18.6699	22.503	37.274		

**[Table/Fig-17]:** HRCT emphysema score vs disease severity.

Clinical feature (MRC)	No. of cases	Mean	SD	Std. Error	95% Confidence interval for mean		p-value
					Lower bound	Upper bound	
Dyspnoea (Gr I)	9	13.556	10.8064	3.6021	5.249	21.862	0.001
Dyspnoea (Gr II)	14	30.643	15.6923	4.1939	21.582	39.703	
Dyspnoea (Gr III)	2	46.500	4.9497	3.5000	2.028	90.972	
Dyspnoea (Gr IV)	5	53.800	4.6583	2.0833	48.016	59.584	
Total	30	30.433	18.6227	3.4000	23.479	37.387	

**[Table/Fig-18]:** HRCT emphysema score verses clinical feature (dyspnoea).

## DISCUSSION

The mean age of the patients in present study was 60 years, with a range of 42 to 80 years. There was a male preponderance, comprising 70% of the total cases. This is consistent with previous studies by Kaya L et al., and who also found a similar age distribution and male preponderance [26]. Dyspnoea was gradually progressive in all patients in the study, which is in line with findings by Tel et al., and Sharma et al., who established a correlation between dyspnoea

and the duration of COPD [27,28]. Physical examination findings were normal in 50% of cases, supporting the notion that physical examination alone is not sensitive in the initial diagnosis of COPD, as shown in a study by Badgett RG et al., [29]. The study also found that non smokers can develop COPD due to household air pollution/biomass fuel exposure, which is in agreement with a study by Salvi SS and Barnes PJ [30].

A positive correlation was found between HRCT emphysema score and smoking, as well as the number of pack-years smoked. This is consistent with studies conducted by Kim et al., Patel et al., and Sashidhar et al., [31-33].

The study found an inverse correlation between FEV1 and HRCT emphysema score, which is in line with previous studies by Kaya et al., and Saraydin et al., [26,34]. However, no significant correlation was found between FEV1/FVC and HRCT emphysema score in present study. Chest X-ray sensitivity was found to be low, consistent with studies by Thurlbeck and Simon and Klein et al., [35,36]. The distribution of emphysema in present study showed upper lobe predominance, similar to a study by Gurney et al., [37]. The mean visual emphysema score in all patients was comparable to the findings of Kaya et al., [26].

The study found that an increase in HRCT emphysema score was associated with decreased lung function, particularly FEV1. This is consistent with the study by Saraydin et al., Additionally, there was a positive correlation between COPD severity and HRCT emphysema score in present study [34]. The correlation between HRCT emphysema score and parameters of pulmonary function testing suggests that the visual scoring method can be used as an initial assessment of emphysema severity. However, there was no significant relationship found between clinical grades of dyspnoea and HRCT emphysema scores in the literature.

### Limitation(s)

Limitations of present study include a small sample size with a predominance of male participants and a focus on patients with moderate to severe obstructive features seeking treatment. Therefore, the findings may not be generalisable to patients with emphysema and preserved lung function.

### CONCLUSION(S)

The HRCT is a valuable tool for detecting and quantifying emphysema in COPD patients, allowing for the identification of structural lung involvement at an early stage before it can be seen on plain chest radiography or detected by pulmonary function tests. The HRCT emphysema score correlates well with functional indices of airflow obstruction and impaired lung capacity. Higher HRCT scores are associated with more severe lung function impairment. Therefore, HRCT can be used as a useful tool in the early detection and quantification of emphysema in COPD patients.

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