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Original Research Article

Role of MDCT in the Evaluation of Copd & Pulmonary Function Test Correlation

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Abstract

Background: Chronic obstructive pulmonary disease (COPD) requires precise structural and functional evaluation to accurately predict disease severity.

Objective: This study evaluated the pattern, distribution, and severity of COPD using qualitative and quantitative multidetector computed tomography (MDCT) parameters, correlating these findings with pulmonary function test (PFT) indices.

Methods: An observational cross-sectional evaluation was performed on the high-resolution computed tomography (HRCT) scans of 50 COPD cases and 30 healthy controls, and the metric data were correlated with spirometry values.

Results: Qualitative emphysema scoring and presence correlated significantly with spirometry indices. Among quantitative metrics, the anterior junction line length, sternoaortic distance, tracheal index, and the thoracic cage ratio and thoracic cross-sectional area normalized to height squared at the inferior pulmonary vein level demonstrated strong correlations with spirometric data. Notably, the quantitative MDCT parameters calculated in this cohort were lower than established Western population standards.

Conclusion: HRCT plays a definitive role in diagnosing COPD and predicting emphysema severity; however, regional variations underscore the need for population-specific reference values.

Keywords: COPD, Multidetector Computed Tomography (MDCT), Pulmonary Function Test, Spirometry, Emphysema Severity.

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Introduction

Chronic Obstructive Pulmonary Disease (COPD) represents a major global health challenge characterized by persistent respiratory symptoms and progressive airflow limitation, driven primarily by chronic bronchitis and emphysema.[1] According to the World Health Organization (WHO), COPD was the third leading cause of death globally in 2019, causing 3.23 million deaths, with nearly 90% of these mortalities occurring in low- and middle-income countries (LMICs).[2]

In India, COPD stands as the second leading cause of death, contributing to over 9.5% of total deaths and over 50% of the national chronic respiratory disease burden.[3] Traditionally, diagnosis relies mostly on Pulmonary Function Tests (PFTs), which offer essential quantitative data on expiratory flow limitation (e.g., FEV, FVC).[4] However, PFTs cannot provide detailed anatomical insight into regional structural variations. Multidetector Computed Tomography (MDCT) overcomes this by offering high-resolution, cross-sectional imaging of the lung parenchyma, airways, and vasculature, which aids in characterizing disease heterogeneity.[5]

While automated in-vivo CT quantification methods are highly accurate for evaluating emphysema, they remain too laborious and computationally demanding for routine clinical workflows. Alternative qualitative visual scoring methods and rapid geometric over inflation measurements offer pragmatic, software-independent diagnostic surrogates that can easily be incorporated into daily reporting. The present study aimed to evaluate the pattern, distribution, and severity of COPD using rapid qualitative and quantitative high-resolution computed tomography (HRCT) imaging parameters and to correlate these radiological metrics directly with standard spirometric PFT indices.

Material and Methods

This observational, cross-sectional study was conducted over a period of 2 years at Depts. of Radio-diagnosis and Respiratory Medicine at our institute with sample size of 50 after approval from institutional ethics committee (IEC App. No: -1206/ 07.02.2023).

The case group included relatively stable, ambulatory, and cooperative COPD patients with an obstructive pulmonary function test (PFT) pattern who underwent HRCT of the thorax. The control group consisted of patients undergoing evaluation for non-COPD conditions with normal HRCT.

Patients with lung malignancy, fibrosis, known tuberculosis sequelae, occupational lung diseases, or those who withheld written consent or were lost to follow-up were excluded. A pre-designed bilingual form was used during patient interviews to record demographic profiles (name, age, sex), physical examinations (height, weight, blood pressure), smoking history, annual exacerbation episodes, and all relevant clinical and radiological findings.

Pulmonary function tests: Pulmonary function tests (PFT) were performed in the Department of Pulmonary Medicine using the RMS Helios 401 spirometer to evaluate the physiological indices required for COPD diagnosis as below:

- Forced vital capacity (FVC),
- Forced expiratory volume in one second (FEV1),
- FEV1/FVC ratio.

GOLD Grades and Severity of Airflow Obstruction in COPD (based on post-bronchodilator FEV1)

In COPD patients (FEV1/FVC < 0.7):

- GOLD 1: Mild -FEV1 ≥ 80% predicted
- GOLD 2: Moderate- 50%≤FEV1< 30% predicted
- GOLD 3: Severe -30%≤FEV1< 30% predicted
- GOLD 4: Very Severe -FEV1 < 30% predicted

HRCT scan techniques [6]: All HRCT scans were performed within 3 weeks of the pulmonary function tests using a 16-slice GE Bright Speed CT scanner at the Department of Radiodiagnosis. Axial, sagittal, and coronal sections (1.25 mm thickness) were reconstructed with high-resolution and standard algorithms (window width: 1500 HU; level: -500 HU) from scans acquired in the supine position during both deep inspiration and expiration using 120 kV, 124 mA, 0.8 s rotation time, and 1.375:1 pitch.

Image Analysis:

Quantitative Indices [7]

Quantitative Index	Definition	Standard Reference Value Mean [SD]
Length of Anterior Junction Line (AJL)	Measured from the posterior surface of the sternum to the point where the pleural folds deviate in the shape of an inverted Y.	1.45cm [0.67]
Sterno-Aortic Distance (SAD)	Measured from the posterior surface of the sternum to the line drawn along the anterior margin of the ascending aorta.	2.7 cm [0.9]
Thoracic Cage Ratio (TCR)	Calculated as the ratio of the anteroposterior (AP) diameter to the transverse diameter of the inner thorax. **Aortic Arch Level** • TCR1: Maximum AP diameter of the right lung.	TCR 1: 0.66 [0.08]
	• TCR2: Midline distance connecting the posterior sternum to the anterior margin of the thoracic vertebrae body.	TCR2: 0.44[0.07]
	Inferior Pulmonary Vein Level • TCR3: Maximum AP diameter of the right lung.	TCR3: 0.75 [0.08]
	• TCR4: Midline distance connecting the posterior sternum to the anterior margin of the thoracic vertebrae body.	TCR4: 0.52 [0.09]
Thoracic Cross-Sectional Area to the Square of Height	The ratio of the average right and left lung cross-sectional areas (assessed via a polygonal area tool in PACS) to the square	TCSA1/Ht2 (Aortic arch level): 98.82cm2/m2 [11.6] TCSA2/Ht2 (Inferior pulmonary vein

Ratio (TCSA/Ht2)	of the patient's height at two distinct anatomical levels	level): 95.41 cm2/m2 [2.35]
Tracheal Index (TI)	The ratio of transverse diameter to anteroposterior diameter of the trachea, measured at a level 1 cm above aortic arch.	Mean [SD]: 0.93 [0.15]
PA/A Calculation [9]	Ratio of main pulmonary artery diameter (measured at bifurcation of left and right pulmonary arteries) to maximum diameter of ascending aorta measured within the same CT plane.	Cutoff value: 0.8

Qualitative Indices: [6]

Emphysema Scoring [8]: Emphysema was evaluated across six distinct lung areas based on two criteria: qualitative severity and volumetric extent.

- Severity was scored on a scale of 0 to 3: 0 indicated no emphysema; 1 indicated low attenuation areas < 5 mm (with or without vascular interruption); 2 indicated low attenuation areas > 5 mm; and 3 indicated low attenuation areas without safe lung parenchyma, potentially accompanied by vascular distortion and interruption.
- Extent of disease involvement was graded on a 4-point scale: 1 point for < 25% involvement, 2 points for 25–50%, 3 points for 50–75%, and 4 points for > 75% involvement.

An individual emphysema score for each of the six lung areas was calculated by multiplying the severity score by the extent points. These regional values were summed to generate a total HRCT emphysema visual score ranging from 0 to 72 points.

Associated Lung Findings [7]: Three additional structural abnormalities—peri bronchial thickening, bronchiectasis, and inhomogeneous attenuation—were assessed independently across all six lung lobes. Each feature was scored dichotomously as either present (1 point) or absent (0 points) per lobe.

This yielded a maximum cumulative score of 6 points for each individual finding across the entire lung. Results were analysed using SPSS version 22 and MS excel.

Results

Among the study population of 80 cases including controls, the 50 COPD cases (42 males, 8 females) were predominantly aged 51–60 years (42%). Most COPD cases presented with breathlessness (29), followed by cough (26) and sputum production (24), while a few experienced fevers from secondary infections. Grade 1 (mild) COPD was the most prevalent at 48%, followed by Grade 2 (32%), Grade 3 (14%), and Grade 4 (very severe) at 6%. On HRCT centriacinar emphysema was the most common (68%), followed by paraseptal emphysema (48%). Across studies by P P Gupta et al. [10], Sanjay Kumar et al. [11] and Dr Shubhangi Gupta et al. [12] centrilobular (centriacinar) emphysema was consistently identified as the most common subtype, followed by paraseptal and panacinar (panlobular) emphysema.

In our study cases exhibited significantly higher median values and greater variability (IQR) than controls across all measured HRCT parameters—including AJL (1.63 vs. 0.42), SAD (2.55 vs. 1.50), and thoracic cage ratios at all levels (TCR1, TCR2, TCR3: $p < 0.0001$; and TCR4) as well as higher mean values for TCSA1/Ht2, consistently indicating more pronounced anatomical abnormalities and disease severity. A study on 128 subjects by Leena Robinson Vimala et al. [6] showed significant differences between cases and controls for spirometric indices and most quantitative HRCT parameters, except for sterno-aortic distance (SAD) Table 1).

HRCT Parameters vs. GOLD Severity Grades (Table 2): Among the quantitative HRCT parameters, AJL and SAD correlated significantly with GOLD severity grades. Furthermore, statistically significant differences or correlations were observed for:

- TCSA2/Ht2 ($p < 0.0001$): Median values increased progressively with higher severity.
- TI ($p < 0.0001$): Median values decreased progressively with higher severity.
- PA/A ($p = 0.002$): Median values increased progressively with higher severity.
- TCR4 ($p = 0.016$): Showed significant variation across grades, peaking notably in Grade 3.

Conversely, no statistically significant differences or correlations were found for TCR1 ($p = 0.509$), TCR2 ($p = 0.619$), TCR3 ($p = 0.113$), or TCSA1/Ht2 ($p = 0.601$), indicating these parameters remain relatively stable across COPD severity levels.

Leena Robinson Vimala et al. [6] found that while TCR measurements and inferior pulmonary vein

TCSA/Ht² correlated with spirometry, AJL length and TI correlated with lung volume. Only four patients had an AJL exceeding 3 cm, and aortic arch TCSA/Ht² showed no spirometric correlation. Finally, the authors established optimal thresholds for predicting impairment: an AJL of 1.3 cm (61% sensitivity, 78% specificity) and an inferior pulmonary vein TCSA/Ht² of 84.7 cm2/m2.

Dr. Shubhangi Gupta et al. [12] observed that a decreasing Tracheal Index (TI), which averaged 0.81 + 0.13, strongly correlated with increasing severity on spirometry. Conversely, the Thoracic Cage Ratio (TCR) and Thoracic Cross-sectional Area/Height² both showed inverse correlations with spirometric variables, while the inverse trend for Sterno-aortic Distance (SAD) was not statistically significant. A significant positive correlation was found between the annual frequency of COPD exacerbations and the PA/A ratio. J. Michael Wells et al. [13] and Michael J Cuttica et al. [14] studies depicted that PA:A ratio of more than 1 had the strongest association with severe exacerbations.

In our study FEV 1 has a strong positive correlation (p-value of <0.0001) with TI, indicating that lung function changes closely with parallel alterations in the tracheal index (Fig.1). Conversely, a significant inverse correlation (correlation coefficient -0.656) was found between FEV1 and TCSA2/Ht2, demonstrating that TCSA2/Ht2 tends to increase as lung function declines (Fig. 2). Studies by Sanjay Kumar et al.[11] , Ajay j. kattakkayam et al.[15] and Dr. Shubhangi Gupta et al.[12] consistently demonstrated that a lower Tracheal Index (TI)—including the presence of a saber-sheath trachea—strongly correlates with advanced COPD severity (GOLD 3 and 4) and reduced spirometric variables like FEV1 and FEV1/FVC, with Dr. Shubhangi Gupta et al.[12] reporting a mean TI of 0.81 + 0.13 that decreased as disease severity progressed.

Both Leena Robinson Vimala et al. [6] and Dr. Shubhangi Gupta et al. [12] observed that the Thoracic Cross-sectional Area scaled to height (TCSA/Ht2)—specifically at the inferior pulmonary vein level—shares a significant inverse correlation with spirometric variables. As per qualitative evaluation, a statistically significant correlation (p < 0.0001) was found between the Total Emphysema Score and GOLD severity grades, with median scores increasing progressively as COPD severity worsened: Grade 1 (5), Grade 2 (10), Grade 3 (22), and Grade 4 (46). Furthermore, the interquartile range (IQR) peaked in Grade 3 at 23, indicating substantial internal variability, whereas Grade 4 had an IQR of 0, reflecting consistently severe and extensive emphysema across all patients in that group. Sakai et al. [16], along with subsequent studies by Miniati et al. [17] and Mochizuki T et al. [18], demonstrated that the HRCT visual score method for disease severity and extent correlates significantly with pulmonary function tests, showing the strongest association with FEV1 and FEV1/FVC ratios.

Table 1: Comparison of quantitative HRCT parameters between cases and controls

Parameter	**cases (N=50)**	**controls (N=30)**	**P value**
	Median (IQR)		
AJL	1.46 (0.5)	0.42 (0.37)	<0.0001
SAD	2.42 (0.55)	1.5 (0.41)	<0.0001
	Median (IQR)		
TCR1	0.71 (0.07)	0.58 (0.07)	<0.0001
TCR2	0.49 (0.07)	0.32 (0.04)	<0.0001
TCR3	0.78 (0.10)	0.65 (0.05)	<0.0001
	Mean ± SD		
TCR4	0.54 ± 0.05	0.36 ± 0.03	<0.0001
TCSA1/Ht2	73.71 ± 6.99	50.85 ± 7.91	<0.0001
	Median (IQR)		
TCSA2/Ht2	88.7 (8.8)	63.6 (15.05)	<0.0001
TI	0.72 (0.13)	0.98 (0.18)	<0.0001
PA/A	0.8 (0.2)	0.7 (0.1)	0.002

Table 2: Correlation between qualitative HRCT parameters and GOLD severity as per PFT

Parameter	**Grade 1**	**Grade 2**	**Grade 3**	**Grade 4**	**P value**
	Median (IQR)				
AJL	1.46 (0.5)	1.6 (0.9)	2.1 (0.44)	3.1 (1.70*)	0.040
SAD	2.42 (0.55)	2.67 (0.65)	2.86 (0.7)	2.88 (1.72*)	0.044
	Mean ± SD				
TCR1	0.7 ± 0.05	0.71 ± 0.03	0.7 ± 0.12	0.71 ± 0.05	0.509
TCR3	0.77 ± 0.06	0.79 ± 0.05	0.84 ± 0.07	0.80 ± 0.08	0.113

TCR4	0.53 ± 0.04	0.54 ± 0.04	0.60 ± 0.04	0.54 ± 0.06	0.016
TCSA1/Ht2	72.33 ± 7.29	75.28 ± 5.66	74.82 ± 7.70	73.82 ± 10.98	0.601
	Median (IQR)				
TCR2	0.47 (0.07)	0.49 (0.07)	0.49 (0.08)	0.49 (0.2*)	0.619
TCSA2/Ht2	83.4 (17.05)	89.5 (5.7)	93.6 (9.1)	94.4 (6.4*)	<0.0001
TI	0.77 (0.1)	0.68 (0.06)	0.62 (0.06)	0.49 (0.08*)	<0.0001
PA/A	0.8 (0.1)	0.9 (0.28)	1.0 (0.2)	1.0 (0.4*)	0.002

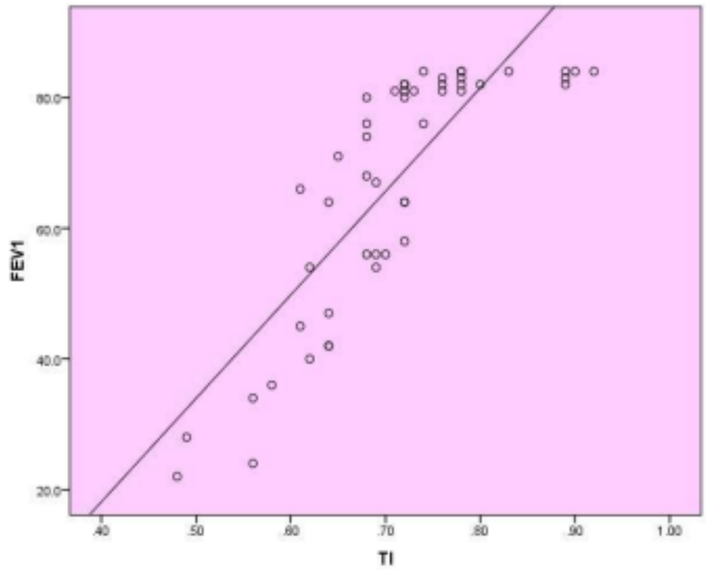

Figure 1: Scatter plot showing strong positive correlation of tracheal index with FEV1

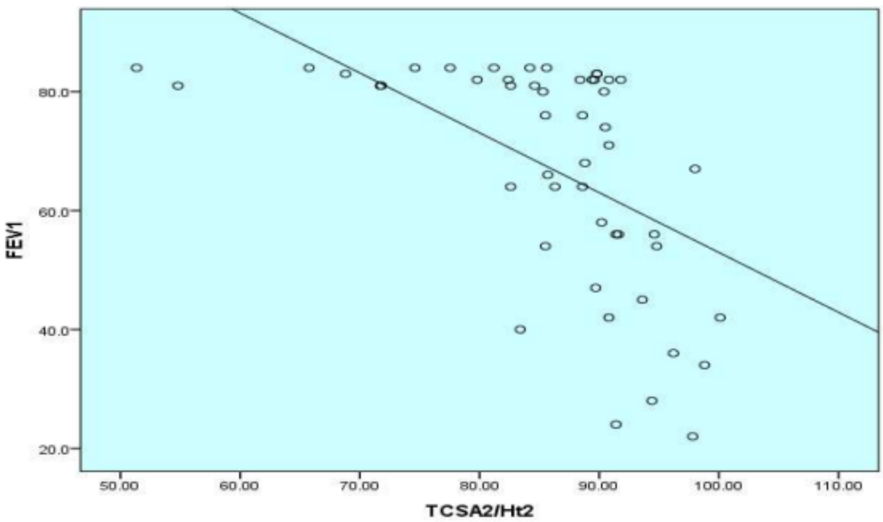

Figure 2: Scatter plot showing strong inverse correlation of TCSA2/Ht2 with FEV1

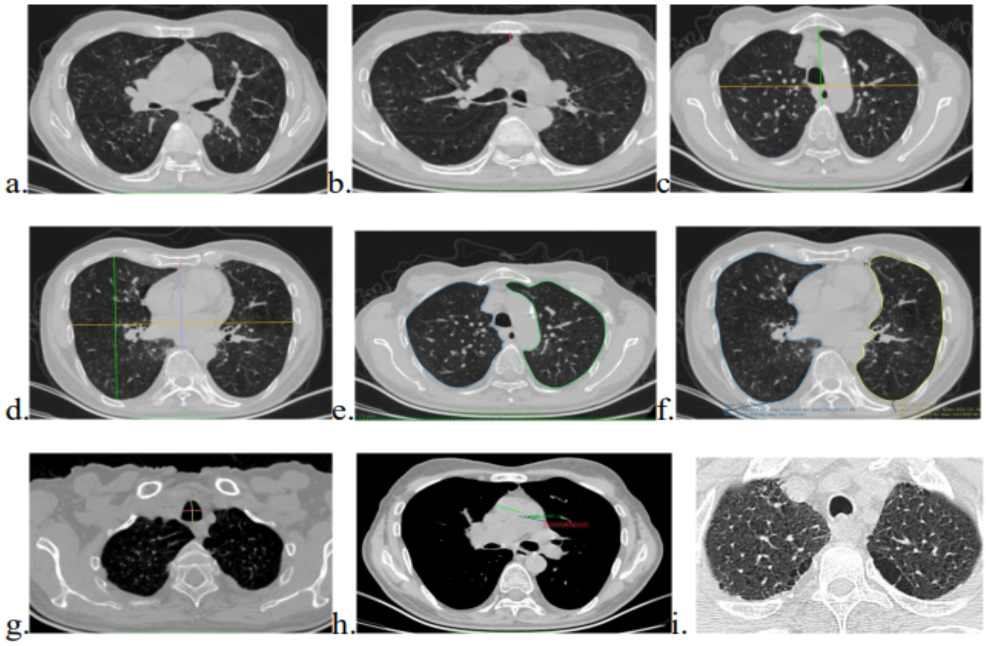

Figure 3: 56Y male smoker with breathlessness; Spirometry shows mild airflow obstruction (FEV1/FVC < 0.7, FEV1 85%, FVC 121%) consistent with GOLD Stage 1 COPD and HRCT parameters as below.

Table 3: Quantitative HRCT parameters of above case

HRCT parameters	
Anterior junctional line	1.4cm
Sterno-aortic distance	2.18cm
TCR1, TCR2, TCR3, TCR4	0.67, 0.44, 0.75, 0.48
TCSA1/Ht2, TCSA2/Ht2	65.8cm2/m2, 74.6cm2/m2
TI	0.74
PA/A	0.7
Pattern of emphysema	Paraseptal emphysema
Total emphysema score	6

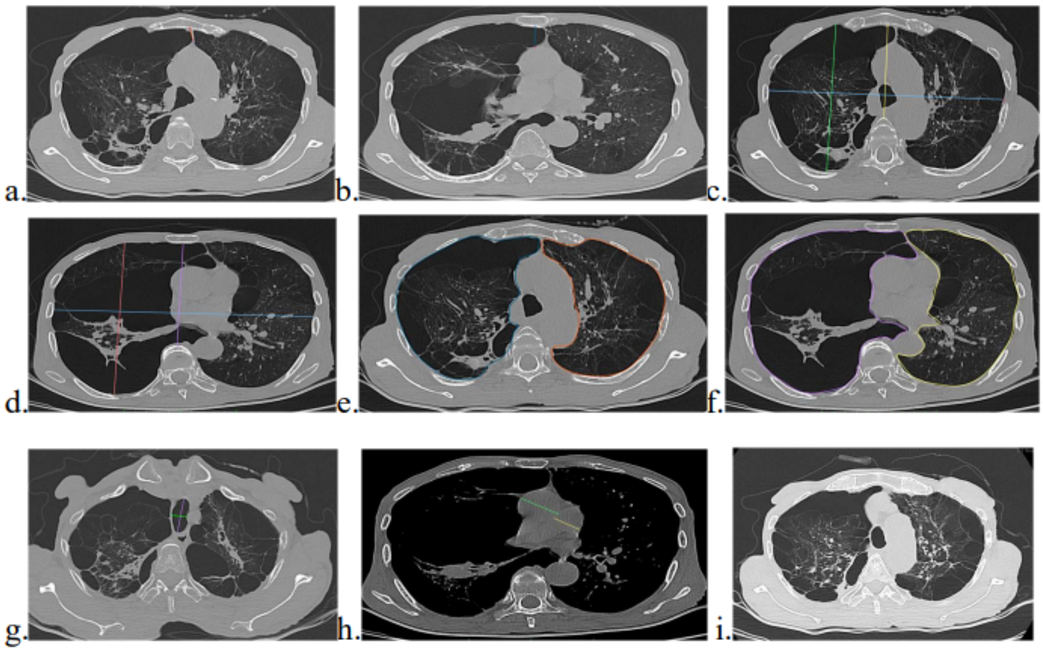

Figure 4: 66y, male smoker with productive cough, breathlessness, pedal edema and mild fever. Spirometry: FEV1-28%, FVC-50%, FEV1/FVC < 0.7 consistent with GOLD Stage 4 COPD with HRCT parameters as below.

Table 4: Quantitative HRCT parameters of above case

HRCT parameters	
Anterior junctional line	1.5 cm
Sterno-aortic distance	2.28 cm
TCR1, TCR2, TCR3, TCR4	0.59, 0.38, 0.71, 0.47
TCSA1/Ht2, TCSA2/Ht2	66.16 cm2/m2, 94.4 cm2/m2
TI	0.49
PA/A	0.7
Pattern of emphysema	Paraseptal emphysema with bullae
Total emphysema score	46

Conclusions

Quantitative HRCT parameters (TI, AJL, SAD, TCR4, and TCSA2/m^2 at the inferior pulmonary vein) and visual emphysema scoring significantly correlate with FEV1, making HRCT vital for assessing COPD severity and emphysema distribution. Notably, quantitative thresholds are lower in the Indian population than in Western cohorts. Additionally, the pulmonary artery-to-aortic ratio effectively predicts acute exacerbation severity. Future research should integrate AI-driven HRCT assessments with functional indices—such as 6MWT, mMRC, CAT, DLCO, RV, and TLC—to enhance diagnostic accuracy.

Limitations

Study limitations include a smaller sample size introducing potential result variability, unassessed inter-observer variation, and a more time-consuming manual workflow. Furthermore, additional PFT metrics (PEFR, DLCO, RV, TLC, RV/TLC, and DLCO/VA) could not be correlated due to unavailability.

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