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Correlation Of HRCT Thorax And PFT Parameters In Diagnosing And Grading COPD Severity

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Abstract

Purpose: *To determine the link between high-resolution computed tomography (HRCT) parameters and pulmonary function test (PFT) indices in COPD patients and to find imaging signals that indicate disease severity.*

Materials and Methods: *Spirometry and HRCT thorax were performed on 130 clinically diagnosed COPD patients in this cross-sectional investigation. Quantitative HRCT parameters evaluated: anterior junction line length, sterno-aortic distance, thoracic cage ratio, TCSA/Ht², and tracheal index. Goddard's score, peribronchial thickening, bronchiectasis, and inhomogeneous attenuation were qualitative. We conducted Pearson and Spearman correlation studies between HRCT parameters and PFT indicators (FEV_1, FVC, and FEV_1/FVC).*

Results: *Significant negative correlations were observed between FEV_1 and structural parameters such as sterno-aortic distance ($r = -0.492$, $p < 0.001$), thoracic cage ratio ($r = -0.432$, $p < 0.001$), and TCSA/Ht² ($r = -0.501$, $p < 0.00$). Goddard's score and inhomogeneous attenuation showed the strongest inverse correlations with both FEV_1 ($\rho = -0.704, -0.637$) and FVC ($\rho = -0.658, -0.638$). The FEV_1/FVC ratio showed weaker but significant positive correlations with some HRCT features, notably inhomogeneous attenuation ($\rho = 0.288$, $p = 0.001$). Tracheal index showed no significant correlation with FEV_1 or FVC.*

Conclusion: *HRCT parameters, particularly TCSA/Ht² and Goddard's scoring, correlate strongly with pulmonary function, indicating their utility as imaging biomarkers for disease severity in COPD. HRCT can complement spirometry in assessing structural and functional impairment, enabling a more comprehensive evaluation of COPD.*

Keywords: *Emphysema, thoracic cage ratio, Goddard's score, air trapping, pulmonary function test, high-resolution CT, COPD.*

INTRODUCTION

COPD, the fourth leading cause of adult deaths worldwide, is a global public health issue. In India, the prevalence among adult men ranges from 4–10%, with rising recognition across Asian populations [1,2]. COPD encompasses chronic bronchitis and emphysema, which often overlap and are difficult to distinguish clinically or via pulmonary function tests (PFTs) alone.

Although PFT gives minimal information on structural lung changes, it is still the gold standard for diagnosing and grading chronic obstructive pulmonary disease (COPD). Additional imaging options include high-resolution computed tomography (HRCT), which can highlight airway and parenchyma pathologies [3]. HRCT is recognized as the most precise tool although conventional in vivo quantification approaches may not be applicable to everyday clinical contexts for detecting emphysema [4,5][6].

This study employs accessible qualitative and quantitative HRCT parameters, such as Goddard's scoring and thoracic morphometric indices, which are easy to implement in daily reporting. These metrics aim to reflect emphysema severity and lung overinflation without the need for specialized software. Considering the limited data from the Indian population, this research also explores population-specific reference thresholds.

While prior studies have demonstrated CT's utility in detecting emphysema and air trapping [7], the present study seeks to correlate HRCT findings with PFT parameters. Objective HRCT metrics (e.g., thoracic cage ratio, anterior junction line, and sterno-aortic distance) and standardized qualitative scores (e.g., Goddard's method, airway thickening) were assessed to evaluate structural-functional relationships [8,9].

By aligning HRCT-based anatomical evaluation with functional impairment observed in PFTs, this study aims to refine diagnostic accuracy, support early disease detection, and improve personalized COPD management strategies [10].

MATERIALS AND METHODS

An Indian tertiary care center's radiodiagnosis department undertook a cross-sectional research over the course of a year. A total of 130 individuals with a clinical diagnosis of a research included COPD patients who underwent pulmonary function testing (PFT). Taking into consideration a 10% non-response rate, the sample size was determined using the usual methodology.

Patients included were those with a confirmed clinical diagnosis of COPD who had undergone PFT. Those with imaging findings suggestive of fibrosis, effusion, infection, pleuroparenchymal mass, post-tubercular sequelae, pregnancy, or inability to perform CT or PFT due to poor respiratory effort were excluded.

HRCT thorax was performed using a 16-slice CT scanner (GE Revolution ACTS). Scans extended from C6 to L2 during full inspiration with breath-hold. Acquisition was done at 120 kVp and 80 mAs, with a 0.5 mm slice thickness and 1.0 mm interval, providing near-isotropic images. Image evaluation was performed using PACS, and all parameters were assessed by the principal investigator in consultation with a senior radiologist.

Quantitative HRCT Parameters:

Anterior Junction Line (AJL): Measured as the anteroposterior distance between the inverted Y-shaped sternal back and the pleural reflections' divergence point.

Sterno-aortic Distance: Measured normally AP distance goes from the rear of the sternum to the front of the ascending aorta at the aortic arch.

Thoracic Cage Ratio (TCR): Reflecting chest hyperinflation, the anteroposterior diameter to transverse thoracic diameter ratio at the aortic arch

Area of the thoracic cavity divided by height squared (TCSA/Ht²): Computed by averaging the cross-sectional areas of both lungs and normalizing as a morphometric proxy for lung volume, to the patient's height squared.

Tracheal Index: The ratio of the anterior to posterior diameter to the transverse diameter, measured 1 cm above the aortic arch, indicates the saber-sheath shape or deformed tracheal morphology.

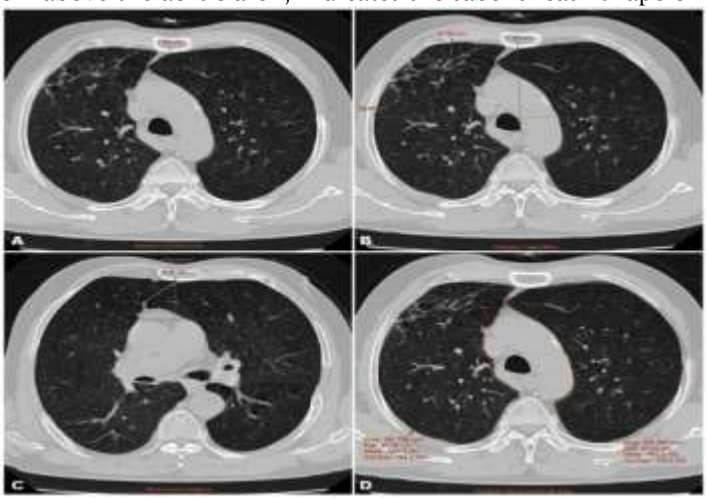

Figure 1: Detailed chest computed tomography showing quantitative COPD features. A: Anterior junction line. B: Thoracic cage ratio. C: Sterno-aortic distance. D: Thoracic cross-sectional area.

Qualitative HRCT Parameters:

Goddard's Scoring: A visual scoring system assessing emphysema severity in six lung zones (upper, middle, and lower zones of both lungs). Each zone is graded scoring between 0 (no emphysema) to 4 (>75% participation), with a maximum score of 24[8].

Peribronchial Thickening: Evaluated in each lobe; presence was scored as 1 per lobe with a total maximum score of 6.
Bronchiectasis: Presence of bronchial dilatation scored 1 per involved lobe, with a maximum score of 6.

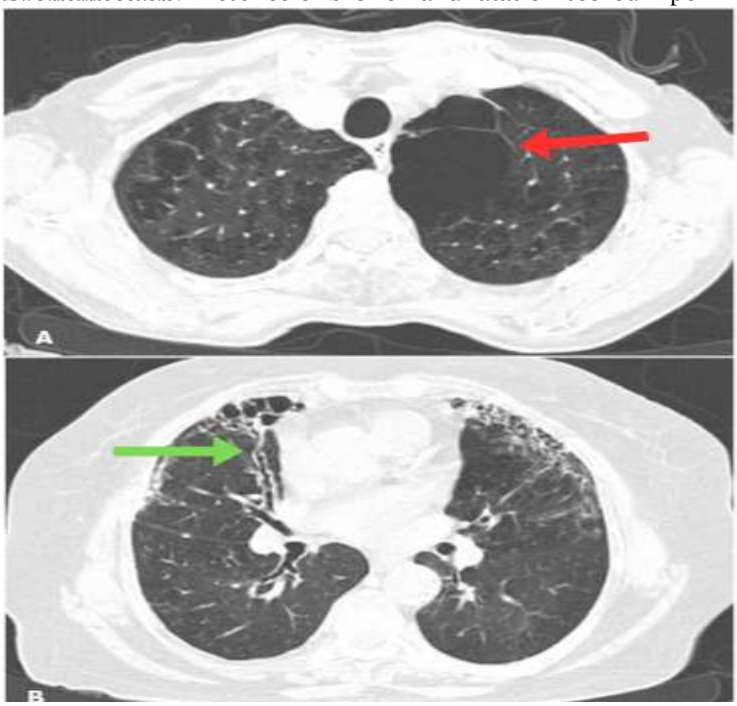

FIGURE 2: Chest computed tomography with high resolution showing quantitative data in a COPD patient. A: Centrilobular emphysema (red arrow). B: Bronchiectasis (green arrow)

Inhomogeneous Attenuation: Presence of mosaic or uneven attenuation pattern scored per lobe (maximum score: 6), reflecting small airway obstruction or air trapping.

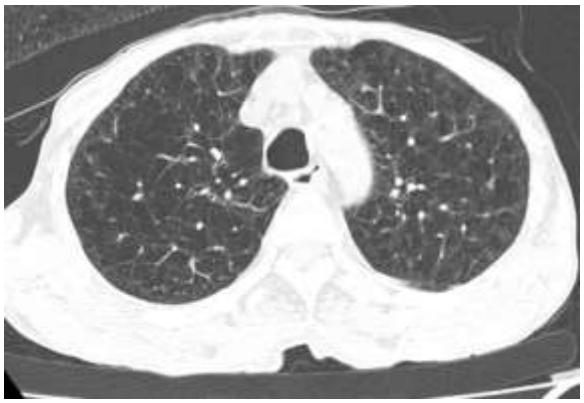

FIGURE 3: Presence of inhomogeneous attenuation as shown in chest high-resolution computed tomography

COPD diagnosis and severity were classified using the GOLD criteria, with FEV1/FVC <70% confirming airflow limitation, and post-bronchodilator FEV1 used for grading severity.

Statistical Analysis

The SPSS version 30.0 was used for the statistical analysis. Descriptive statistics described the data, while Pearson's and Spearman's tests examined HRCT-PFT connections. A p-value below 0.05 indicated statistical significance.

The Institutional Ethics Committee authorized the study after all participants gave written informed consent.

RESULTS

There were 130 COPD patients in all, with men making up the majority (81.5%). The age bracket of 61–70 years accounted for 32.3% of the total, with 55.4% of those people smoking. Based on GOLD classification, the majority were in Stage II (43.1%), followed by Stage III (31.5%), Stage IV (15.4%), and Stage I (10%).

Quantitative HRCT Parameters:

The mean anterior junction line (AJL) length increased with disease severity, ranging from 5.09 ± 1.56 mm in Stage I to 8.74 ± 1.55 mm in Stage IV. Sterno-aortic distance and thoracic cage ratio (TCR) also showed a progressive rise across GOLD stages. Mean TCSA/height² decreased with severity, while the tracheal index showed a significant reduction, consistent with "saber-sheath" trachea.

Qualitative HRCT Parameters:

The Goddard scoring showed a significant increase with COPD stage ($p < 0.001$), with Stage IV patients averaging 19.2. The presence of bronchiectasis and peribronchial thickening increased in frequency and severity across stages. Inhomogeneous attenuation was highest in Stage III (mean: 4.85) and IV (mean: 4.70), compared to lower stages. The PFT, various quantitative and qualitative parameters are given in table 1.

Table 1: High-Resolution CT Parameters and PFT Statistics

Parameter	Mean	Standard Deviation	p-value
Length of Anterior Junction Line (mm)	13.42	6.22	<0.001
Sterno-aortic Distance (mm)	25.65	9.88	<0.001
Thoracic Cage Ratio	0.92	0.35	<0.001
Thoracic Cross-sectional Area / Height² (cm²)	98.04	10.68	<0.001
Tracheal Index	0.82	0.12	0.021
Goddard's Scoring (0–24)	12.68	6.22	<0.001
Peribronchial Thickening (0–6)	3.17	1.43	<0.001
Bronchiectasis (0–6)	3.23	1.61	<0.001
Inhomogeneous Attenuation (0–6)	3.78	1.60	<0.001
FVC (L)	1.13	0.35	<0.001
FEV_1 (L)	0.84	0.23	<0.001
FEV_1 / FVC Ratio	0.75	0.05	0.003

Table 2: Correlation of Quantitative HRCT Parameters with Pulmonary Function Tests (n = 130)

Parameter	FVC (r/ρ)	p-value	FEV_1 (r/ρ)	p-value	FEV_1/FVC (r/ρ)	p-value
Back Junction Point(mm)	–0.163	0.064	–0.126	0.152	–0.032	0.716
Sterno-aortic Distance (mm)	–0.352**	<0.001	–0.492**	<0.001	+0.208*	0.017
Thoracic Cage Ratio	–0.391**	<0.001	–0.432**	<0.001	+0.333**	<0.001
Area over the chest/ Ht²	–0.526**	<0.001	–0.501**	<0.001	+0.148	0.094
Tracheal Index	+0.090	0.310	+0.054	0.544	–0.202*	0.021
Goddard's Scoring	–0.658**	<0.001	–0.704**	<0.001	+0.204*	0.020
Peribronchial Thickening	–0.525**	<0.001	–0.495**	<0.001	+0.202*	0.021
Bronchiectasis	–0.301**	0.001	–0.321**	<0.001	+0.177*	0.043
Inhomogeneous Attenuation	–0.638**	<0.001	–0.637**	<0.001	+0.288**	0.001

Note: Pearson's correlation used. * *Significant ($p < 0.05$) and* **High ($p < 0.001$) are denoted by*

A decrease in lung function with increasing thoracic structural abnormalities was shown by significant negative associations between sterno-aortic distance, thoracic cage ratio, and TCSA/Ht² and both FVC and FEV_1 ($p < 0.001$). TCSA/Ht² had the most robust association. The tracheal index correlated weakly with FVC and FEV_1 but Observed a slight inverse relationship with FEV_1/FVC ($r = -0.202$, $p = 0.021$). Interestingly, FEV_1/FVC positively correlated with sterno-aortic distance and thoracic cage ratio,

suggesting a possible compensatory airflow pattern. These findings underscore the link between thoracic morphology and pulmonary function in COPD.

Table 3: Correlation of Qualitative HRCT Parameters with Pulmonary Function Tests (n = 130)

Parameter	FVC (ρ)	p-value	FEV_1 (ρ)	p-value	FEV_1/FVC (ρ)	p-value
Goddard's Scoring	–0.658**	<0.001	–0.704**	<0.001	+0.204*	0.020
Peribronchial Thickening	–0.525**	<0.001	–0.495**	<0.001	+0.202*	0.021
Bronchiectasis	–0.301**	0.001	–0.321**	<0.001	+0.177*	0.043
Inhomogeneous Attenuation	–0.638**	<0.001	–0.637**	<0.001	+0.288**	0.001

Note: A Pearson's correlation was determined. *Significant, with Both $p < 0.05$ and $p < 0.001$ are very significant.

This table presents Spearman's correlations between HRCT features and pulmonary function in COPD patients. Goddard's scoring and inhomogeneous attenuation showed the strongest negative correlations with FVC (ρ = –0.658 and –0.638) and FEV_1 (ρ = –0.704 and –0.637), indicating greater lung function decline with emphysema severity. Peribronchial thickening and bronchiectasis also showed significant, though weaker, negative correlations with FVC and FEV_1. Interestingly, FEV_1/FVC ratio showed weak but significant positive correlations with all HRCT parameters, particularly inhomogeneous attenuation (ρ = 0.288, $p = 0.001$), suggesting complex effects on airflow obstruction. These results highlight emphysema as the dominant structural determinant of lung function impairment in COPD.

Table 4: Mean HRCT Parameter Values by GOLD Stage and Correlation with FEV_1%

HRCT Parameter	GOLD I (Mean ± SD)	GOLD II	GOLD III	GOLD IV	Correlation with FEV_1% (r)	Significance (p)
Anterior Junction Line (mm)	5.09 ± 1.56	6.12	7.10	8.74	–0.828	<0.001
Sterno-aortic Distance (mm)	18.80 ± 4.82	21.42	23.93	25.65	–0.819	<0.001
Thoracic Cage Ratio	0.65 ± 0.12	0.72	0.85	0.91	–0.830	<0.001
TCSA/Height² (cm²/m²)	109.40 ± 8.29	101.76	91.14	86.22	+0.816	<0.001
Tracheal Index	0.98 ± 0.06	0.89	0.82	0.73	–0.819	<0.001
Goddard's Score (0–24)	6.48 ± 2.08	10.25	16.40	19.20	–0.885	<0.001
Bronchiectasis (Score 0–6)	1.32 ± 0.45	2.11	3.48	4.26	–0.703	<0.001
Peribronchial Thickening (0–6)	1.15 ± 0.28	2.21	3.52	4.11	–0.682	<0.001

HRCT Parameter	GOLD I (Mean ± SD)	GOLD II	GOLD III	GOLD IV	Correlation with FEV_1% (r)	Significance (p)
Inhomogeneous Attenuation (0–6)	1.38 ± 0.40	2.64	4.85	4.70	–0.754	<0.001

Table 4 summarizes the progression of HRCT parameters across GOLD stages and their correlation with pulmonary function (FEV_1%). A clear trend was observed where most HRCT metrics, both quantitative and qualitative, changed significantly with increasing disease severity.

Quantitative markers such as the ratio of the thoracic cage, the sterno-aortic distance, the anterior junction line, increased progressively from GOLD Stage I to IV, reflecting hyperinflation and structural remodeling of the thorax. Conversely, thoracic cross-sectional area normalized to height squared ($TCSA/Ht^2$) and tracheal index decreased with worsening disease, indicating volume loss and airway distortion. These changes showed strong inverse correlations with FEV_1, most notably in AJL (r = –0.828), TCR (r = –0.830), and sterno-aortic distance (r = –0.819), all statistically significant ($p < 0.001$).

Among qualitative parameters, Goddard's emphysema score exhibited the strongest negative correlation with FEV_1 (r = –0.885), underlining the relationship between visual emphysema severity and pulmonary impairment. Similar trends were noted with bronchiectasis, peribronchial thickening, and inhomogeneous attenuation, which were more prevalent and severe in higher GOLD stages.

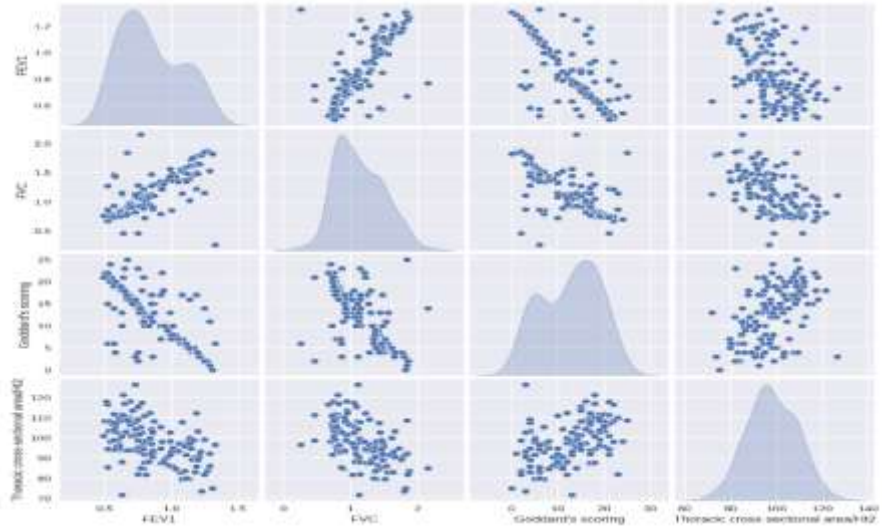

FIGURE 4: Scatter matrix plot shows the relationships between key parameters including FEV1, FVC, Goddard's scoring, and Thoracic cross-sectional area.

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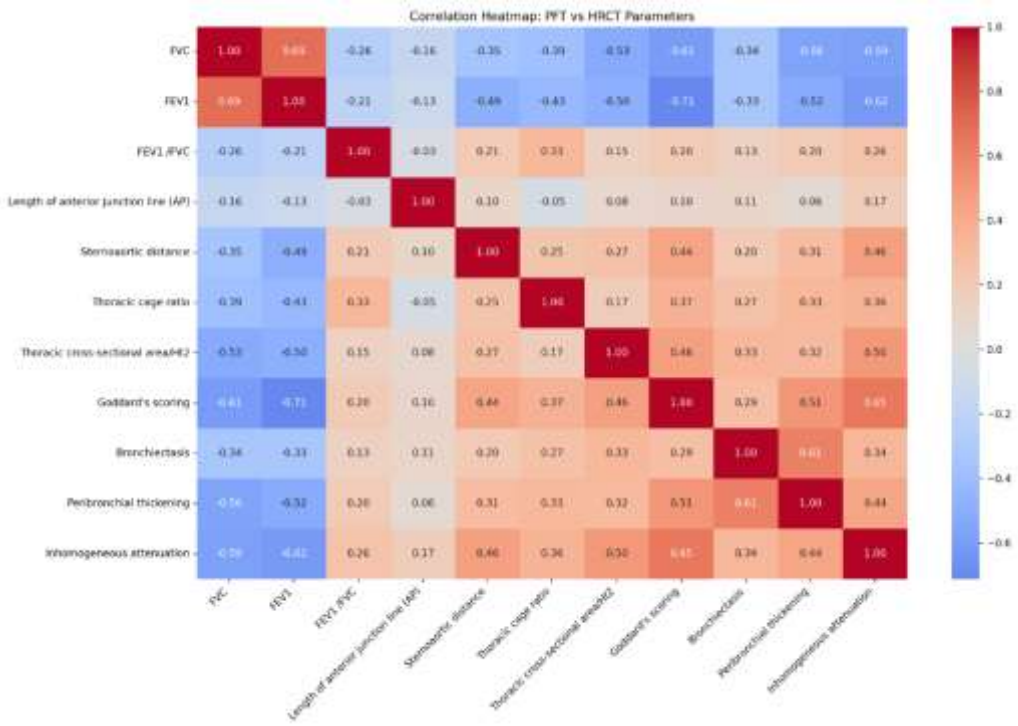

FIGURE 5: Heatmap depicting the correlation between pulmonary function test (PFT) parameters (FVC, FEV_1, FEV_1/FVC) and HRCT-derived structural markers in COPD patients. Strong negative correlations are seen between FVC and FEV_1 with Goddard's score, inhomogeneous attenuation, and peribronchial thickening, indicating reduced lung function with increasing structural abnormalities. Thoracic cage ratio and TCSA/Ht² also show inverse associations. In contrast, FEV_1/FVC exhibits weak-to-moderate positive correlations with several HRCT parameters. Color gradients indicate the direction and intensity of the association: a negative correlation is represented by blue, while a positive correlation is shown by red.

DISCUSSION

Computed tomography (CT) scans are valuable for identifying areas of lung damage in emphysema and air trapping and have been investigated in multiple studies. [11-13] High-resolution computed tomography (HRCT) scans can detect even mild emphysema cases that may not appear on standard lung function tests (spirometry).[14] This makes HRCT a more sensitive tool for early diagnosis.

Emphysema is characterized by fewer and smaller blood arteries and low tissue density (below -910 Hounsfield Units on CT). Computerized tomography (CT) scans provide these and other details on the emphysema's spread in the lungs. To rule out other obstructive lung disorders is the main goal of HRCT in individuals suspected of COPD. Most quantitative variable cutoffs derive from Western research, although they may still apply to Indians as, as is clear.

In terms of both its aims and its methods, this study is distinct from others. Our approach to HRCT evaluation is straightforward and can be seamlessly integrated into routine reporting. In contrast, most prior studies relied on quantitative assessment of emphysema using the "density mask" software, which involves additional costs and is both time-consuming and labor-intensive. [5] Therefore, integrating this method into daily reporting may not be practical, so it was not utilized in our study.

The researchers set out to establish a way to quantify and qualitatively score COPD symptoms in order to better represent the disease's severity.

Among the 130 patients, 96 were males (76%) and 34 were females (24%). Thirty patients (or 23% of the total) were in the study group with GOLD stage 1 disease, fifty percent (50%) had GOLD stage 2 illness, and twenty-five patients (or 27% of the total) had GOLD stage 3 disease. After measurement of the quantitative parameters, it was seen that Spirometry and the thoracic cage ratio were significantly correlated. For measurements made at the carina, a threshold value of 0.75 was set by Gupta et al. [10]. At aortic arch level, 91 patients had a TCR value more than 0.75, indicating that 70% of our cases met this criterion.

The Sterno-aortic distance showed a significant correlation with all the spirometry variables. We found that 127 out of 130 patients had A sterno-aortic distance above 4 cm. In contrast to the control group,

Hagen et al. [15] observed 16 of 22 patients had sterno-aortic distances above 4 cm. The sterno-aortic distance was found to be less than 4 cm in 5 out of 40 instances in the research by Gupta et al. [10].
There was a strong association between spirometry and the Thoracic cross-sectional area per aortic arch height square. According to Kasai et al. [16], the TCSA/Ht2 ratios in the grade IV dyspnoea group were notably higher lower than the values seen found in mixed grade II/III dyspnea groups. Gupta et al. [17] found that 28 out of 40 patients had a TCSA/height² more than 80 cm^2/m^2, measured 1 cm below the aortic arch. Our study showed 52 patients with TCSA/height2 more than 100 cm2/m2 and 125 with greater than 80 cm2/m2.
Out of a total of 10 of 22 patients had AJLs beyond 3 cm, according to Hagen et al. [15]. In our study, anterior junction line did not show significant correlation with PFT parameters.
Tracheal index showed weak correlation with only FEV1/FVC. Trigaux and his co-researchers observed a meaningful correlation related to the tracheal index. [18] Arakawa found a strong correlation between spirometry and the tracheal index in his research [19].
For qualitative assessment, According to Goddard et al. [8], eight scans were performed starting at the very top and working their way down to the very bottom. According to Bergin et al. [5] determined assessed subjective emphysema levels for the lung and each lobe. Miniati etal. [20] employed six hemi-slices from the top of the aortic arch, the commencement of the lower lobe bronchus, and three centimeters above the diaphragm's highest point. In order to develop a subjective emphysema score, Gurney et al. [6] examined all lung areas. There is a strong association between pulmonary function tests (PFT) and the various qualitative emphysema grading methods evaluated by HRCT. Visual scoring was carried out using Goddard's methods on one representative slice of emphysema from each lobe in this investigation. When it came to qualitative evaluation, spirometry indices and Goddard's grading were highly correlated. Total lung score correlated significantly with FEV1 and FVC.
Additionally, we examined the qualitative markers associated with chronic bronchitis, such as peribronchial thickening, bronchiectasis, and uneven lung attenuation. It is important to note that these features are quite non-specific and may also appear in other respiratory diseases. The research conducted by Aziz et al. [21] focused on airway problems linked to emphysema, which may be determined by measuring the degree of bronchiectasis and bronchial wall thickness. Gupta et al. [10,17] found a strong relationship between spirometric indices and characteristics including vascular attenuation, mosaic attenuation, vascular distortion, and the appearance of tiny airways. About a third of those who took part in the study by Brien et al. [22] were found to have bronchiectasis, primarily of the tubular variety. However, in this study we assessed three criteria for persistent bronchitis - bronchiectasis, heterogeneous attenuation, and thickening around the airways. Spirometry demonstrated a strong relationship with all of these variables.

LIMITATIONS

This study has certain limitations. HRCT Differences in lung sizes and acquisition methodologies might cause attenuation levels to fluctuate. Inconsistent breath-holding by some patients likely influenced imaging accuracy. Cross-sectional thoracic measurements were performed manually, which may introduce observer variability. Additionally, other key lung volume parameters such as RV, FRC, and TLC were not assessed.

CONCLUSION

Our research proved that spirometry was significantly correlated with quantitative measures including sterno-aortic distance, thoracic cage ratio and cross-sectional area to height square at the aortic arch.
Emphysema severity could be predicted using qualitative HRCT assessment, which correlated significantly with spirometry. Spirometry measures were significantly correlated with other chronic bronchitis parameters. Therefore, while evaluating chronic obstructive lung disease, HRCT serves specific and different purposes. HRCT is useful for a number of purposes, including ruling identifying additional causes of COPD, forecasting emphysema severity, and arranging treatment.

REFERENCES

1. Hansell DM, Lynch DA, McAdams HP, Bankier AA. Imaging of diseases of the chest. 5th ed. Philadelphia: Elsevier Health Sciences; 2009. p. 1208.
2. Indian Council of Medical Research, Public Health Foundation of India, University of Washington, Institute for Health Metrics and Evaluation. India: Health of the Nation's States. Seattle: Institute for Health Metrics and Evaluation; 2017. p. 214.
3. Kauczor HU, Wielpütz MO. MRI of the lung. Berlin: Springer; 2018. p. 518.

4. Takasugi JE, Godwin JD. Radiology of chronic obstructive pulmonary disease. Radiol Clin North Am. 1998;36(1):29–55.
5. Bergin CJ, Müller NL, Miller RR. CT in the qualitative assessment of emphysema. J Thorac Imaging. 1986;1(2):94–103.
6. Gurney JW, Jones KK, Robbins RA, et al. Regional distribution of emphysema: correlation of high-resolution CT with pulmonary function tests in unselected smokers. Radiology. 1992;183(2):457–63.
7. Coxson HO, Rogers RM. Quantitative computed tomography of chronic obstructive pulmonary disease. Acad Radiol. 2005;12(12):1457–63.
8. Goddard PR, Nicholson EM, Laszlo G, Watt I. Computed tomography in pulmonary emphysema. Clin Radiol. 1982;33(4):379–87.
9. Newell JD Jr. Quantitative computed tomography of lung parenchyma in chronic obstructive pulmonary disease: an overview. Proc Am Thorac Soc. 2008;5(9):915–8.
10. Gupta PP, Yadav R, Verma M, Agarwal D, Kumar M. Correlation between high-resolution computed tomography features and patients' characteristics in chronic obstructive pulmonary disease. Ann Thorac Med. 2008;3(3):87–93.
11. Zompatori M, Fasano L, Mazzoli M, et al. Spiral CT evaluation of pulmonary emphysema using a low-dose technique. Radiol Med. 2002;104(1-2):13–24.
12. Mishima M, Itoh H, Sakai H, et al. Optimized scanning conditions of high resolution CT in the follow-up of pulmonary emphysema. J Comput Assist Tomogr. 1999;23(3):380–4.
13. Coxson HO, Rogers RM. Quantitative computed tomography of chronic obstructive pulmonary disease. Acad Radiol. 2005;12(12):1457–63.
14. Klein JS, Gamsu G, Webb WR, et al. High-resolution CT diagnosis of emphysema in symptomatic patients with normal chest radiographs and isolated low diffusing capacity. Radiology. 1992;182(3):817–21.
15. Hagen G, Kolbenstvedt A. CT measurement of mediastinal anterior junction line in emphysema patients. Acta Radiol 1993; 34: 194-195.
16. Kasai T, Yamada M, Narushima M, et al. Relationship between thoracic cross-sectional area measured on CT and pulmonary function or dyspnea in patients with COPD. Nihon Kokyuki Gakkai Zasshi. 2003;41(7):526–30.
17. Gupta PP, Yadav R, Verma M, et al. High-resolution computed tomography features in patients with chronic obstructive pulmonary disease. Singapore Med J. 2009;50(2):193–200.
18. Trigaux JP, Hermes G, Dubois P, et al. CT of saber-sheath trachea: Correlation with clinical, chest radiographic and functional findings. Acta Radiol. 1994;35(3):247–50.
19. Arakawa H, Kurihara Y, Nakajima Y, et al. Computed tomography measurements of overinflation in chronic obstructive pulmonary disease: Evaluation of various radiographic signs. J Thorac Imaging. 1998;13(3):188–92.
20. Miniati M, Filippi E, Falaschi F, et al. Radiologic evaluation of emphysema in patients with chronic obstructive pulmonary disease. Chest radiography versus high resolution computed tomography. Am J Respir Crit Care Med. 1995;151(5):1359–67.
21. Aziz ZA, Wells AU, Desai SR, et al. Functional impairment in emphysema: contribution of airway abnormalities and distribution of parenchymal disease. AJR Am J Roentgenol. 2005;185(6):1509–15.
22. O'Brien C, Guest PJ, Hill SL, et al. Physiological and radiological characterisation of patients diagnosed with chronic obstructive pulmonary disease in primary care. Thorax. 2000;55(8):635–42.