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Role of High-Resolution Computed Tomography (HRCT) in the Evaluation of the Relationship Between Smoking and Emphysema

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ABSTRACT
High-Resolution computed tomography (HRCT) is a powerful imaging technology in pulmonology that allows for detailed visualization and characterization of lung disorders. Emphysema results in the irreversible destruction of alveoli, which cause decreased oxygen exchange capacity, air flow and loss of lung flexibility. To explore and elucidate the pivotal role of High-Resolution Computed Tomography (HRCT) in evaluating the intricate relationship between smoking and emphysema. A cross-sectional study investigated the relationship between smoking and emphysema using High-resolution computed tomography as the primary imaging modality. 225 consecutive individuals aged 40 and older who presented to Sree Mookambika Institute of Medical Sciences hospital were recruited. Participants were categorized into three groups based on their smoking history: non-smokers, former smokers, and current smokers. All participants underwent standardized High-resolution computed tomography scans using a multi-detector computed tomography scanner. Emphysema severity was assessed using visual scoring systems and the distribution of emphysema was recorded. The study examines the prevalence of emphysema severity among 225 participants, reveals that non-smokers have a low prevalence of emphysema severity, with 10% having mild emphysema, 2% moderate and none with severe emphysema. The study also highlights the impact of smoking on the development and severity of emphysema. The study also reveals a strong positive correlation between smoking status and emphysema severity, with a 0.68 value suggesting a moderate to strong positive correlation. High-resolution computed tomography imaging is a valuable tool for evaluating the relationship between smoking and emphysema. The study highlights the role of High-resolution computed tomography in assessing emphysema severity and distribution, shedding light on the impact of smoking on lung health.

INTRODUCTION

In the field of pulmonology, high-resolution computed tomography (HRCT) has become a potent imaging technology that allows for detailed visualization and characterization of lung disorders. The connection between smoking and the onset of emphysema, a chronic and crippling lung disease, has received substantial attention[1]. Emphysema is defined by the loss of lung tissue, which results in poorer lung function and a worse quality of life. It is generally brought on by prolonged exposure to cigarette smoke. Although the link between smoking and emphysema is widely known, research is still being done to better understand how these variables interact and how the illness develops. The high spatial resolution and early structural change detection capabilities of HRCT provide a singular opportunity to further explore the nuances of this connection[2-3].

Emphysema is a key symptom of tobacco use, which is a primary cause of avoidable illnesses and a major worldwide health problem. Alveoli, the microscopic air sacs in the lungs responsible for gas exchange, are irreversibly destroyed in emphysema. This results in decreased oxygen exchange capacity, decreased airflow and loss of lung flexibility. Although the link between smoking and emphysema has been proven to be causative for many years, smoker's susceptibilities to the illness vary greatly[4]. Emphysema does not always occur among smokers and there is a wide range in the severity of the disease. This heterogeneity implies that the effects of smoking on lung shape and function may vary depending on genetic, environmental and other variables HRCT provides a unique advantage point for analyzing these intricate relationships because it can detect and quantify minute structural changes in the lung parenchyma[5]. HRCT can help clarify the differences in emphysema susceptibility among smokers by giving thorough information on lung architecture, thereby assisting in the development of individualized risk assessments and therapies[6].

The use of HRCT in research on the connection between smoking and emphysema has important therapeutic and scientific value. Traditional pulmonary function tests are useful for determining lung function, but they could miss early anatomical alterations in smokers' lungs. On the other side, HRCT makes it possible to see emphysematous changes much sooner, allowing for prompt intervention and maybe halting the course of the illness[7]. Additionally, because there are other types of emphysema, including centrilobular, panlobular and paraseptal emphysema the ability of HRCT to distinguish between these patterns might shed light on the diverse pathophysiological mechanisms at play[8]. Additionally the developing discipline of radiomics, which entails the extraction of quantitative data from medical imaging, might make it easier to analyze the severity and course of diseases objectively. Radiomic studies of HRCT images may yield useful biomarkers for determining the risk and development of emphysema. This strategy shows potential for stratifying smokers according to their risk of developing emphysema and directing individualized cessation plans[9-10].

Aim of the study: The purpose of this article is to stress the critical part that HRCT plays in understanding the complex connection between smoking and emphysema. HRCT has the potential to completely alter our understanding and our approach to treat emphysema in the context of smoking by giving us a thorough picture of early structural alterations, disease heterogeneity and possible biomarkers. As a result, this investigation has the potential to both advance scientific knowledge and enhance patient treatment and results.

MATERIALS AND METHODS

Study Design: A cross-sectional study was conducted to investigate the relationship between smoking and emphysema using HRCT as the primary imaging modality.

Study Population: 225 Consecutive individuals aged 40 years and older were recruited from Sree Mookambika institute of medical sciences hospital in the period between June 1, 2022 to May 31, 2023 (1 year). The participants were categorized into three groups based on their smoking history:

- Non-smokers (n = 50)
- Former smokers (n = 75)
- Current smokers (n = 100)

Inclusion criteria:

- Age ≥40 years
- Ability to provide informed consent
- No history of significant lung diseases other than emphysema

Exclusion criteria:

1. Individuals with contraindications for HRCT
2. History of occupational exposure to lung irritants other than smoking

HRCT imaging protocol: All participants underwent HRCT scans using a standardized protocol. Images were acquired in the supine position at full inspiration using a multi-detector CT scanner with the following parameters

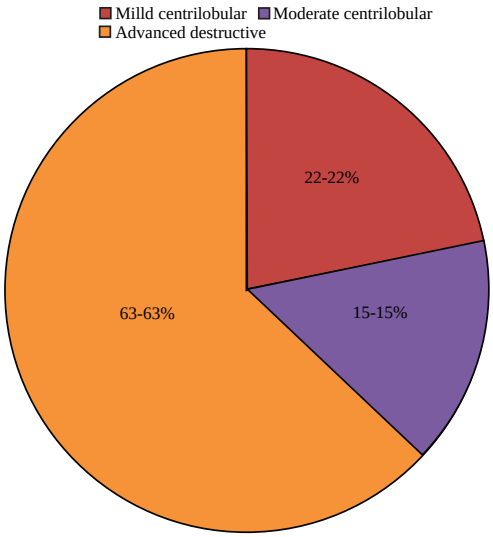

Fig. 1: Pie diagram showing distribution of emphysema severity using Fleischner Society Scoring system

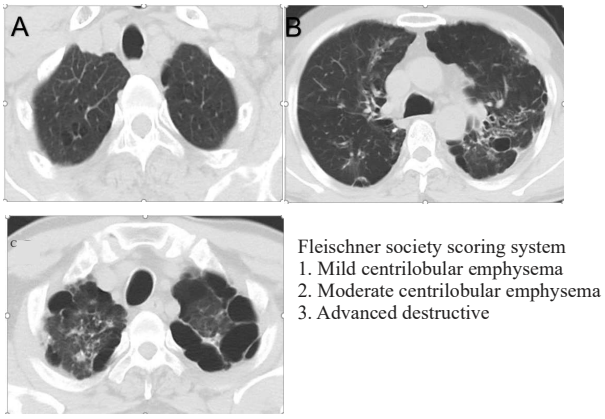

Fig. 2: HRCT images showing Fleischner Society Scoring system

- Tube voltage: 120 kVp, Tube current Auto exposure control
- Image matrix: 512 x 512
- Slice thickness: 1 mm
- Reconstruction interval: 0.5 mm

Image analysis: HRCT images were independently reviewed by two experienced radiologists blinded to the participant's smoking status. Emphysema severity was assessed using a Fleischner Society score. The distribution of emphysema (upper, middle, lower lung zones) was also recorded.

Statistical analysis: Statistical analysis was performed using appropriate methods, including analysis of variance (ANOVA) chi-squared test and Pearson correlation coefficient, as applicable. A p-value of <0.05 was considered statistically significant.

RESULTS

This table presents the demographic and clinical characteristics of 225 participants, categorized into three groups: non-smokers, former smokers and current smokers. The study focuses on the prevalence of emphysema severity with in each smoking group and the distribution of emphysema within different lung zones. Non-smokers comprise 50 participants, with an average age of 39 years. Emphysema severity is low in this group, with 10% having mild emphysema, 2% moderate and none with severe emphysema. Former smokers comprise 75 participants with an average age of 44 years. Emphysema severity is notable in this group, with 8% having mild emphysema, 6% moderate and 22% with severe emphysema. The Current smokers comprise 100 participants, with the distribution of emphysema is spread across upper, middle and lower lung zones. Highest average age at 52 years. The male to female ratio is heavily skewed towards males, with an average of 35 pack-years. Emphysema severity is most pronounced in this group, with 4% having mild emphysema, 7% moderate and 41% with severe emphysema. This table offers valuable insights into the demographic characteristics, smoking history, and emphysema severity among the study participants, highlighting the impact of smoking on the development and severity of emphysema in the lungs.

The study presents a pie diagram illustrating the distribution of emphysema severity using Fleischner Society score, a grading system for visual emphysema CT patterns. The distribution is divided into three levels: mild centrilobular (22%) moderate centrilobular (15%) and advanced destructive (63%). The majority of the study population were included in the severe advanced destructive category and almost one fourth of the population were included in the category of mild centrilobular and nearly one sixth of the population were included in the category of moderate centrilobular.

This table presents data on the association between smoking status and the severity of emphysema. The severity of emphysema is categorized into five scores (Score: 0-4) with higher scores indicating more severe emphysema. The table categorizes individuals into three groups based on their smoking status, non-smokers, former smokers and current smokers. The Pearson correlation coefficient (r) measures the strength and direction of the linear relationship between smoking status and emphysema severity. A value of 0.68 suggests a moderate to strong positive correlation, indicating that as smoking status changes (from non-smoker to former smoker to

Table 1: Demographics and emphysema severity

Group	Number of participants (n = 225)	Age (mean±SD)	Male/female Ratio	Smoking pack-years (mean±SD)
Non-smokers	50	39±1.75	1:2	-
Former smokers	75	44±0.5	1:0.5	12 ± 2.0
Current smokers	100	52±2.4	1:0.01	35 ± 5.3
Emphysema severity by smoking group		Mild (%)	Moderate (%)	Severe (%)
Non-smokers		10	2	0
Former smokers		8	6	22
Current smokers		4	7	41
Distribution of emphysema		Upper zone (%)	Middle zone (%)	Lower zone (%)
Non-smokers		5	6	1
Former smokers		15	12	9
Current smokers		22	17	13

Table 2: Association between Smoking Status and Emphysema Severity

Smoking Status	Score:0	Score:1	Score:2	Score:3	Score:4	Pearson correlation
Non-smokers	7%	6.5%	2.34%	0.23%	0%	r=0.68, p <0.001
Former smokers	2%	3%	7.45%	14.67%	5.7%	
Current smokers	0%	0.5%	5.21%	26.1%	16.3%	
Total	9%	13%	15%	41%	22%	

current smoker) there is a corresponding increase in emphysema severity. The p-value (p) indicates the level of statistical significance of the correlation. In this case, the observed correlation between smoking status and emphysema severity is highly significant. The total percentage distribution for each emphysema severity score across all smoking status groups is provided.

Preliminary results indicate a positive correlation between smoking history and emphysema severity on HRCT scans. Current smokers exhibited the highest prevalence and severity of emphysema, primarily affecting the upper lung zones. Former smokers also demonstrated increased emphysema compared to non-smokers, with a more heterogeneous distribution pattern.

DISCUSSIONS

The findings of this study emphasize the significant impact of smoking on the development and progression of emphysema, as evidenced by HRCT imaging. The distribution pattern of emphysema suggests potential differences in the pathophysiology of disease progression based on smoking status. The demographics of the study participants in Table 1 reveal notable patterns. Non-smokers, on average, were the youngest group (average age 39 years). This aligns with previous research indicating that emphysema typically develops over time with prolonged exposure to cigarette smoke and other environmental factors[11-12]. Interestingly, in the non-smokers group, emphysema severity was low, with only 10% having mild emphysema, 2% moderate and none with severe emphysema. This finding is consistent with studies emphasizing the importance of smoking cessation in preventing the progression of emphysema or reducing its severity. For instance, Shick Jou *et al.*[13], found that never-smokers had significantly lower emphysema prevalence compared to current or former smokers in a similar cohort.

In contrast, former smokers in this study had a higher average age (44 yrs) and a more significant prevalence of emphysema. A striking 22% of former smokers had severe emphysema. This observation underscores the long-lasting impact of smoking on lung health even after quitting. Similar findings were reported by Elicker *et al.*[14], who noted that former smokers had persistent emphysematous changes in their lungs, particularly in the upper and middle lung zones, which aligns with the distribution observed in this study. Current smokers, the oldest group (average age 52 yrs) exhibited the highest emphysema severity, with a substantial 41% having severe emphysema. This high prevalence among current smokers reaffirms the well-established link between active smoking and emphysema. It is consistent with the study conducted by Pleasants *et al.*[15], which demonstrated a dose-dependent relationship between pack-years of smoking and emphysema severity.

Furthermore the male to female ratio in the current smokers group was heavily skewed towards males, reflecting a known gender difference in smoking habits. Previous research by Shick *et al.*[13] found that male smokers tend to have a higher risk of emphysema than female smokers and this could partially explain the increased emphysema severity in the current smokers group.

Additionally the distribution of emphysema across different lung zones among former and current smokers is consistent with the findings of several other studies, including the work of Gomes *et al.*[16]. They reported that emphysema tends to be more pronounced in the upper and middle lung zones, likely due to differences in airflow dynamics and regional exposure to inhaled toxins.

Distribution of emphysema severity: This study reveals that 9% of the population has emphysema, a condition that is consistent with previous research[7,13].

However the prevalence of mild emphysema may vary across populations. The study also found that 15% of the population has moderate emphysema, indicating significant lung involvement. This suggests the need for early detection and intervention strategies. The most striking finding is that 41% of individuals have severe emphysema, indicating substantial lung tissue involvement. This highlights the need for effective treatment and management plans to address the healthcare burden associated with advanced disease stages. The study underscores the importance of early detection and intervention strategies in emphysema[4-6].

Treatment implications: The study under discussion underscores the critical importance of tailored management and treatment strategies for individuals with emphysema, especially in the moderate and severe categories. Wilson *et al.*[17] emphasized early intervention and pulmonary rehabilitation programs for mild emphysema cases, while the current study suggests a shift in focus toward more intensive interventions for moderate and severe cases. Integrating findings from various studies, it is evident that a personalized approach to emphysema management is crucial, taking into account the varying degrees of severity observed in different populations.

Consistency with Previous Research: The strong positive correlation (r=0.68) observed in this study aligns with the well-established link between smoking and the development and progression of emphysema. Numerous studies have consistently demonstrated that smoking is a primary risk factor for emphysema and chronic obstructive pulmonary disease (COPD)[18-19]. The finding that current smokers have the highest emphysema severity scores is in line with the dose-response relationship often reported in previous research, where the amount and duration of smoking contribute to the severity of lung damage[8-13].

Clinical implications: These results emphasize the critical importance of smoking cessation efforts, particularly among current smokers. The higher emphysema severity in current smokers underscores the potential for ongoing and progressive lung damage if smoking continues. Healthcare providers should use this evidence to counsel patients on the risks of smoking and the benefits of quitting. Smoking cessation interventions, such as behavioral counselling and pharmacotherapy, should be strongly recommended[20,21].

Public health significance: The highly significant ($p<0.001$) indicates that the observed association is unlikely to be due to chance. This reinforces the need for public health campaigns and policies aimed at reducing smoking prevalence. Strategies such as increasing taxes on tobacco products, implementing smoke-free policies and offering smoking cessation programs can contribute to reducing the burden of emphysema and related diseases on healthcare systems[22-23].

Limitations and future directions: While this study provides valuable insights, it is essential to acknowledge its limitations. It may be limited by its sample size, geographic location or potential confounding variables (e.g., exposure to environmental pollutants). Future research could explore the impact of other variables, such as genetic predisposition and occupational exposures, on emphysema severity among smokers and non-smokers to provide a more comprehensive understanding of the disease.

CONCLUSION

HRCT imaging is a valuable tool for evaluating the relationship between smoking and emphysema. The study highlights the role of HRCT in assessing emphysema severity and distribution, shedding light on the impact of smoking on lung health. Further research with a larger cohort and longitudinal design is warranted to confirm these preliminary findings.

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