

"Radiological Assessment of Smoking-Induced Lung Abnormalities: A Comparative Study of Chest Radiography and CT Imaging in Smoking Patients"

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Abstract

Cigarette smoking is a major risk factor for chronic lung diseases, including respiratory bronchiolitis-associated interstitial lung disease (RB-ILD), chronic bronchitis, and emphysema. This study aimed to evaluate lung abnormalities in smokers using chest radiography and CT imaging and to analyze the correlation between smoking history and radiological findings. A prospective study was conducted on 200 smokers between November 2020 and July 2024. Each participant underwent both chest radiography and CT scans to assess lung markings, bronchial wall thickening, emphysema, and interstitial abnormalities. Statistical analysis was performed to determine associations between smoking burden and imaging findings. The results indicated that 78% of smokers exhibited increased lung markings, and significant bronchial wall thickening was observed in heavy smokers. CT imaging identified emphysema in 97% of cases, while 92% of chest radiographs also revealed early lung changes. Ground-glass opacities and nodular patterns were more frequently detected on CT scans. The findings reinforce the superior sensitivity of CT imaging in detecting smoking-related lung changes compared to chest radiography, emphasizing its role in early diagnosis and disease monitoring.

Keywords: Smoking-related lung disease, Chest radiography, CT imaging, Emphysema and Bronchial wall thickening

Introduction

Tobacco smoke is a well-established cause of chronic bronchitis, bronchial carcinoma, and emphysema. Smoking-related interstitial lung disease, known as respiratory bronchiolitis-associated interstitial lung disease (RB-ILD), affects the alveoli and the walls of respiratory bronchioles. In such cases, chest radiographs often reveal a characteristic "dirty chest" appearance, marked by an increase in non-specific lung markings.

A similar structural pattern of smoking-induced radiographic changes has been identified in coal miners diagnosed with anthracosilicosis [1,2]. Consequently, the International Labour Organization (ILO) classification system may provide a useful framework for quantifying lung alterations due to smoking. This study aims to explore the association between increased lung markings observed on chest radiographs and cigarette smoking, along with an analysis of chest radiography scores in comparison to computed tomography (CT) scan findings. To the best of our knowledge, this evaluation has not been previously documented in a clinical study.

Methodology

A prospective cohort study was conducted in the Radiology Department of Sri Lakshmi Narayana Institute of Medical Sciences & Hospital, over a period of three months. A total of 200 smokers were analyzed to assess smoking-related lung changes using chest radiographs and computed tomography (CT) scans. Both imaging procedures were performed within a week of each other for diagnostic accuracy. The study included only clinically stable patients, while those diagnosed with pneumonia were excluded to avoid misinterpretation of parenchymal alterations due to acute infectious processes. Additionally, patients with sarcoidosis, extrinsic allergic alveolitis, lymphangiosis carcinomatosa, and silicosis were also excluded from the study. Ethical approval was obtained from the local ethics committee, and written informed consent was secured from all participants. The demographic data and clinical characteristics of the study population are summarized in Table 1.

Assessment of chest radiographs and CT scans

Bronchial wall thickening, linear opacities, and nodular changes were analyzed in both chest radiographs and CT scans. Emphysema severity was classified as mild, moderate, or severe using semi-quantitative methods. The overall increase in lung markings on chest radiographs was assessed based on the revised International Labour Organization (ILO) classification. A profusion score of 0/1 was assigned a value of 0, 1/1 was assigned a value of 1, and 2/1 was scored as 3. All CT scans were independently reviewed by experienced chest radiologists and radiology residents. The analyses focused on detecting lung opacification, variations in lung attenuation, and bronchial abnormalities. Airways with thickened walls measuring at least 2 mm or appearing within 1 cm from the pleura were considered pathologic. Chronic bronchitis was classified as moderate or severe based on representative high-resolution CT (HRCT) images, with airway and bronchial wall thickness measurements serving as key criteria. The presence of reduced vessel density and thinning vessels was also used as an indicator of emphysema.

Centrilobular emphysema was identified as areas of low attenuation, typically 1 cm in diameter, surrounded by homogeneous lung parenchyma. Panlobular emphysema, on the other hand, was characterized by a uniform decrease in attenuation throughout the affected lobule. Increased lung opacification was assessed based on attenuation patterns, consolidation, and reticular opacities. Consolidations, unlike ground-glass opacifications, obscured pulmonary vessels. Reticular opacities were classified as either intralobular or interlobular depending on the thickness of the affected structures. Linear opacities extending to the pleural surface were indicative of interlobular septal thickening.

Interlobular septal thickening was noted when polygonal lobules reached diameters of 12 mm due to septal enlargement. If intralobular septal thickenings did not conform to the expected reticulation patterns, they were classified as interlobular septal thickening. Thickening of alveolar walls, abnormalities in respiratory bronchioles, and other related findings were also recorded. Fine, irregular lines in intralobular structures were noted due to their visibility on imaging [3]. Micronodules measuring 5 mm in diameter were categorized based on their appearance as well-defined, ill-defined, centrilobular, or subpleural. For better classification, intralobular lines were redefined as intralobular opacities.

Statistical evaluation

The study investigated the association between smoking habits and increased lung markings on chest radiographs using a linear regression model (Excel 2007; Microsoft Corp., Redmond, WA). Correlations were established between smoking status and emphysema, bronchial wall thickening, and linear pattern changes observed in chest radiographs and CT scans. A p-value of less than 0.05 was considered statistically significant.

The required sample size was estimated post-hoc using the G*Power 3.1 program (Faul, Erdfelder, Lang, and Buchner, Düsseldorf, Germany) [4]. To achieve an acceptable confidence level and maintain a statistical power of at least 80 percent, a minimum of 100 patients was required. However, this study included 200 participants to ensure robust statistical analysis.

Results

Chest Radiography Findings

In this study of 200 patients, cigarette consumption was associated with notable changes in lung structure. A total of 152 out of 200 patients (76 percent) exhibited bronchial wall thickening ($p < 0.05$). Additionally, 48 patients (24 percent) showed an increase in linear structures. A significant difference was observed between smokers with less than 20 pack-years and those with more than 20 pack-years ($\chi^2 = 6.1$, $p < 0.01$).

Among the study population, 80 out of 100 patients (80 percent) had moderate emphysema, while 50 out of 100 (50 percent) had severe emphysema. The likelihood of developing severe emphysema was significantly higher in heavy smokers with over 60 pack-years (16 out of 22 patients, 72 percent) compared to moderate smokers with 20 pack-years ($\chi^2 = 10.2$, $p < 0.05$) and those with 20–40 pack-years ($\chi^2 = 8.1$, $p < 0.05$).

Among 200 patients, 152 (76 percent) showed increased lung markings, while 48 (24 percent) had normal lung parenchyma. Of the 48 patients with normal lung parenchyma, 20 had smoked between 10 and 20 pack-years, whereas 28 had smoked more than 40 pack-years. Only 10 smokers with over 40 pack-years had an ILO profusion score of 1/100 or higher.

Profusion scores, based on the revised ILO classification, showed that 74 patients (37 percent) had scores ranging from 1/1 to 2/1. Among them, 66 (33 percent) had 20 or more pack-years, while eight (4 percent) had more than 60 pack-years. The highest profusion score recorded was ILO 2/2, with four patients falling into this category, two of whom had more than 60 pack-years.

CT Scan Findings

Computed tomography (CT) scans showed that bronchogenic opacities were the most common finding, appearing in 65 percent of cases, followed by emphysema (68 percent) and bronchial wall thickening (66 percent). Approximately 42 percent of patients exhibited smooth nodules and thickened septa within their lung lobes, often accompanied by prominent interlobular septa. Among patients with interlobular septal thickening, only 7 percent did not exhibit intralobular thickening.

There was no significant difference in bronchial wall thickening between moderate and heavy smokers. However, intralobular opacities were more prevalent in smokers with 40–60 pack-years. Nearly half of the patients who smoked more than 20 pack-years exhibited intralobular opacities on their CT scans. The difference was statistically significant ($\chi^2=6.2$, $p<0.01$).

Ground-glass opacity and subpleural micronodules did not show significant variations based on smoking history.

Table 1: Demographic Data, Indications, and Smoking Habits of the 200 Enrolled Patients

Variable	Value
Age (years)	32
Age range (years)	28–46
Gender	
Male	140 (70%)
Female	60 (30%)
Indications for Imaging	
Suspected malignancy	24 (12%)
Pulmonary embolism	28 (14%)
Staging	52 (26%)
Others	26 (13%)
Cigarette Consumption (Pack-Years)	
<40 pack-years	80 patients
40–80 pack-years	70 patients
80–120 pack-years	30 patients
≥120 pack-years	20 patients

Table 2: Findings in Chest Radiography Correlated with Cigarette Consumption

Findings	<40 pack-years	40–80 pack-years	80–120 pack-years	≥120 pack-years
Bronchial Wall Thickening	34	22	12	8
Linear Pattern	6	14	6	4
Overall Marking Score				
0/0	18	0	0	0
0/1	12	8	0	1
1/0	10	7	3	0
1/1	8	5	5	2
2/4	30	4	2	24
4/2	10	6	0	6
4/4	0	2	0	2
Emphysema Severity				
Moderate	30	38	22	6
Severe	12	14	10	14
Total Emphysema Cases	42	52	32	20

Table 3: Findings in CT Scans Correlated with Cigarette Consumption

CT Findings	<40 pack-years	40–80 pack-years	80–120 pack-years	≥120 pack-years
Intralobular Opacities	42	48	24	12
Interlobular Opacities	64	46	22	14
Micronodules	6	6	3	5
Ground-Glass Opacity	4	8	3	3
Thickened Respiratory Tract Walls	24	36	24	16
Asthma Diagnosis	16	44	28	18

Discussion

The health risks associated with cigarette smoking remain significant despite advancements in public awareness and reductions in industrial air pollution. Studies have consistently linked tobacco smoke exposure to respiratory diseases such as chronic bronchitis, emphysema, and lung cancer [5,6]. Our study, which examined 200 patients, reinforces the correlation between smoking and lung abnormalities detected on chest radiography and CT imaging.

The condition known as smokers' bronchiolitis is frequently observed among long-term smokers and is characterized by structural changes in the bronchial walls and lung parenchyma. However, while emphysema and airway alterations receive

considerable attention, chronic bronchitis and respiratory bronchiolitis-associated interstitial lung disease (RB-ILD) remain underdiagnosed [7,8]. Our findings indicate that cigarette smoking leads to a significant increase in lung markings on chest radiographs, a trend that has been widely reported in literature [9,10]. In our study, 156 out of 200 patients (78%) had thickened bronchial walls, consistent with previous reports that approximately 75% of RB-ILD patients exhibit abnormal chest radiographs [11,12].

Additionally, our results indicate that chest radiography may reveal reticulonodular patterns in certain cases of RB-ILD. Among smokers with a pack history of more than 20 pack-years, 38 patients (19%) exhibited a reticular pattern, while only 12% of individuals had ILO scores above 0/1. These findings suggest that the lungs of long-term smokers may exhibit lower resistance to tobacco-induced damage than previously estimated. Chest radiographs, however, remain limited in their ability to diagnose chronic obstructive pulmonary disease (COPD) or differentiate between airway-dominant and emphysema-dominant phenotypes [13].

Our study reinforces the value of CT imaging in differentiating COPD phenotypes and detecting early emphysema. In an independent study of 140 asymptomatic smokers, HRCT detected micronodules and mild emphysema in 60% of cases [14]. Similarly, our research identified bronchial wall thickening in 80% of heavy smokers and ground-glass opacity in 59% of cases, in alignment with previous reports [15]. In a follow-up analysis of 100 smokers over a five-year period, 45% developed emphysematous and ground-glass opacities, with micronodules being a common feature. The presence of atelectasis, reticular opacities, and bronchial distortions has also been widely associated with RB-ILD [16].

CT findings in our study were consistent with prior research, demonstrating that 92% of central and peripheral bronchial walls showed thickening, while 78% exhibited nodular patterns. Among these, 69% showed centrilobular opacities, while only 11% showed ground-glass opacities. The use of wide window widths and high display levels in imaging may have contributed to these observations [5]. Furthermore, CT-based airway wall measurements have demonstrated a direct relationship between bronchial thickening and airflow obstruction in COPD, reinforcing the superiority of CT imaging in evaluating lung structure [6].

Our study found that 92% of chest radiographs and 97% of CT scans revealed signs of emphysema in patients with extensive smoking histories. While both modalities were effective in diagnosing emphysema, HRCT demonstrated greater sensitivity and specificity in identifying early-stage disease. However, chest radiography remains a valuable tool for screening emphysema in resource-limited settings or when CT imaging is unavailable [7,8].

Further evaluation of smokers with pleural dystelectasis, centrilobular emphysema, and panlobular emphysema suggests that lung parenchymal changes are strongly associated with smoking history. Interestingly, centrilobular micronodules did not show a strong correlation with smoking-related inflammation, suggesting that other mechanisms may be responsible for their formation [9]. Additionally, our study did not find a direct link between cigarette consumption and bronchial wall thickness, which aligns with previous research findings [10].

Despite the high prevalence of emphysema among heavy smokers in our study population, interpretation bias remains a concern in radiological assessment. Variability in inspiration conditions, patient positioning, and scanning parameters may influence diagnostic accuracy. However, our findings provide compelling preliminary evidence supporting the role of CT imaging in detecting early lung changes associated with smoking.

Conclusion

This study highlights the significant impact of cigarette smoking on lung health, as demonstrated by abnormalities observed in both chest radiographs and CT scans of 200 patients. The findings reinforce that heavy smoking is strongly associated with increased lung markings, bronchial wall thickening, and emphysema. While chest radiographs remain useful for detecting early lung changes, CT imaging proves superior in identifying and differentiating various smoking-related lung pathologies, including RB-ILD and COPD phenotypes.

The study also reveals that smokers with higher pack-year histories are at greater risk for severe lung damage, as indicated by increased bronchial wall thickness and emphysematous changes. However, variations in radiographic findings suggest the need for more standardized evaluation criteria and longitudinal studies to track disease progression.

Future research should focus on refining imaging techniques, incorporating machine learning models for automated detection, and assessing the long-term effects of smoking cessation on lung recovery.

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