ORIGINAL ARTICLE

Dual pathology, dual burden: Functional impact of emphysema and fibrosis in Hypersensitivity Pneumonitis

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ABSTRACT

Background and aim: Hypersensitivity pneumonitis (HP) is a complex interstitial lung disease with heterogeneous presentations. In some patients, the radiological coexistence of emphysema and fibrosis creates a distinct functional phenotype that complicates disease progression and management. This study aimed to evaluate the functional impact of combined emphysema and fibrosis in HP patients and to identify clinical factors associated with this dual pathology.

Methods: We retrospectively analyzed 214 patients diagnosed with HP between 2010 and 2023. Patients were classified into three groups: fibrotic HP (F-HP), non-fibrotic HP (NF-HP), and combined emphysema with fibrosis (CE-HP). Statistical analyses were performed using SPSS v22.0. Univariate logistic regression was used to evaluate factors associated with severe functional impairment (FVC <50% and DLCO <35%).

Results: Of the 214 patients, 62.1% had F-HP, 35.5% had NF-HP, and 12.6% exhibited CE-HP. Patients with CE-HP were more likely to be older than 65 years (51.9%, p=0.001), predominantly male (74.1%, p=0.01), and more frequently had a history of smoking (51.9%, p=0.001) compared to other groups. Univariate analyses revealed that CE-HP was significantly associated with an increased risk of severe FVC impairment (OR 2.92, 95% CI 1.01–7.76, p = 0.03). While emphysema alone showed a moderate inverse correlation with DLCO (r = –0.56, p < 0.001) , the association between the CE-HP phenotype and severe DLCO reduction (<35%) did not reach statistical significance in this cohort (p = 0.36).

Conclusions: The coexistence of emphysema and fibrosis in HP represents a distinct clinical phenotype with significant functional impairment. Since the competing mechanical effects of these dual pathologies can lead to a

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deceptive preservation of lung volumes, clinicians should prioritize DLCO and HRCT monitoring over spirometry alone for accurate assessment and individualized management of CE-HP patients.

Key words: hypersensitivity pneumonitis, fibrosis, emphysema, lung function, dual pathology, radiological phenotype

Introduction

Hypersensitivity pneumonitis (HP) is an interstitial lung disease caused by repeated exposure to inhaled antigens in susceptible individuals (1). The disease manifests with variable clinical, radiologic, and functional features, often reflecting the cumulative effects of immune-mediated inflammation and subsequent fibrosis (2,3). In recent years, advances in imaging have highlighted the coexistence of fibrotic and emphysematous changes in a subset of HP patients, a finding that suggests a complex interplay between inflammatory and alveolar structural remodeling mechanisms within the lung parenchyma (4–6). Recent data from Sarcoidosis, Vasculitis and Diffuse Lung Diseases have further emphasized the heterogeneous clinical presentation of hypersensitivity pneumonitis across different patient populations (7). While fibrosis has long been recognized as a major determinant of disease progression and mortality, the simultaneous presence of emphysema introduces a dual burden on respiratory mechanics and gas exchange (8–10,14). This combined phenotype—termed "combined pulmonary fibrosis and emphysema" (CPFE) when seen in other contexts—may similarly modify the functional trajectory of HP patients (11,12). However, evidence characterizing this entity within HP remains limited and heterogeneous. Previous reports, including comprehensive reviews and cohort studies, have shown that patients with hypersensitivity pneumonitis and coexistent emphysema are more frequently older, male, and have a history of smoking, resembling demographic patterns observed in fibrosing interstitial lung diseases with emphysematous involvement (1,13). Despite these observations, few studies have quantified the contribution of emphysema to functional impairment in HP, and most have not addressed its clinical implications in a systematic manner (15–17). Therefore, the present study aimed to analyze the prevalence, clinical correlates, and functional impact of combined emphysema and fibrosis in a well-characterized single-center HP cohort. We further sought to determine whether this dual pathology constitutes a distinct functional phenotype within the HP spectrum.

Materials and methods

Study design and population

This retrospective observational study included 214 consecutive patients diagnosed with HP at the Atatürk Sanatoryum Training and Research Hospital, between January 2010 and December 2023. Diagnosis was established according to the ATS/JRS/ALAT HP guideline criteria, integrating clinical history, radiologic findings (HRCT), bronchoalveolar lavage (BAL) results, and, where available, histopathology (18).

Data collection

Demographic characteristics (age, sex, smoking history), antigen exposure, clinical presentation, and radiologic patterns were extracted from medical records. Age was dichotomized at 65 years, as this threshold is commonly used in interstitial lung disease studies to reflect older age and was close to the median age of the study population. HRCT images were reviewed by two experienced radiologists blinded to clinical data. The extent of fibrosis and emphysema was semi-quantitatively scored as <10%, 10–30%, or

>30% of total lung volume. Pulmonary function tests (PFTs) performed within one month of diagnosis were analyzed, including forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and diffusing capacity for carbon monoxide (DLCO), expressed as percentages of predicted values.

Patient grouping

Patients were categorized into three groups:

1. **Non-fibrotic HP (NF-HP):** HRCT without fibrotic changes.
2. **Fibrotic HP (F-HP):** HRCT showing reticulation, traction bronchiectasis, or honeycombing.
3. **Combined emphysema and fibrosis (CE-HP):** HRCT demonstrating both fibrotic changes and clearly demarcated areas of emphysema in upper or peribronchovascular zones.

Statistical analysis

Statistical analyses were conducted using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Categorical variables were presented as frequencies and percentages. Normality of continuous variables was assessed using the Kolmogorov–Smirnov test and visual inspection of histograms. Comparisons between categorical variables were performed using the chi-square test or Fisher's exact test when appropriate. For comparisons across hypersensitivity pneumonitis (HP) radiological subtypes (emphysema, fibrosis, combined emphysema and fibrosis), overall group differences were evaluated using chi-square analysis. To evaluate factors associated with severe pulmonary function impairment, defined as forced vital capacity (FVC) <50% predicted and diffusing capacity of the lung for carbon monoxide (DLCO) <35% predicted, univariate logistic regression analyses were performed. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). Multivariate analysis was not performed due to the limited number of outcome events to avoid model overfitting. A p-value <0.05 was considered statistically significant.

Results

The demographic and baseline clinical characteristics of the study population are summarized in Table 1. A total of 214 patients with hypersensitivity pneumonitis (HP) were included in the study. The mean age distribution showed that 62 patients (29.0%) were older than 65 years. Females constituted 48.1% (n=103) of the cohort. A history of smoking was present in 109 patients (50.9%). Regarding radiological subtypes, emphysema was detected in 32 patients (15.0%), fibrosis in 133 (62.1%), and combined emphysema and fibrosis in 27 (12.6%). Seventy-six patients (35.5%) had neither emphysema nor fibrosis. Severe pulmonary function impairment was observed in 27 patients (12.6%) for FVC <50% predicted and in 18 patients (8.4%) for DLCO <35% predicted. In the emphysema group (n = 32), patients aged ≤65 years were more frequent than those >65 years (53.1% vs. 46.9%, p = 0.02). Male sex predominated (75.0%, p = 0.01). Smoking was more common among patients with emphysema (65.7%), although this did not reach statistical significance (p = 0.07). In the fibrosis group (n = 133), age ≤65 years was significantly more frequent (57.9%, p = 0.001). Sex distribution was not significantly different (p = 0.15). Smoking was significantly associated with fibrosis (56.4%, p = 0.04). In the combined emphysema and fibrosis group (n = 27), patients older than 65 years were more common (51.9%, p = 0.001). Male predominance was observed (74.1%, p =

Table 1. Demographic data n = 214

	n	(%)
Age >65	62	(29.0)
Sex (Female)	103	(48.1)
Smoking	109	(50.9)
Emphysema	32	(15.0)
Fibrosis	133	(62.1)
Emphysema and fibrosis together	27	(12.6)
No emphysema and fibrosis	76	(35.5)
FVC <50	27	(12.6)
DLCO <35	18	(8.4)

(%) Column percentages. *Abbreviations:* FVC: forced vital capacity, DLCO: diffusing capacity of the lung for carbon monoxide.

0.01). Smoking status was significantly associated with this combined phenotype (51.9%, p = 0.001). Comparisons of demographic, clinical, and functional characteristics across study groups are presented in Table 2. Despite their association with the CE-HP phenotype, age >65 years, sex, and smoking history were not independently associated with severe functional impairment defined as FVC <50% or DLCO <35% (all p > 0.05). Emphysema was significantly associated with severe FVC reduction (OR 2.86, 95% CI 1.12–7.25, p = 0.03), but not with severe DLCO impairment (p = 0.27). The regression analysis evaluating predictors of severe functional impairment is presented in Table 3. Fibrosis was independently associated with both severe FVC reduction (OR 3.01, 95% CI 1.09–8.30, p = 0.03) and severe DLCO impairment (OR 5.40, 95% CI 1.20–24.14, p = 0.03). Patients with combined emphysema and fibrosis had an increased risk of severe FVC impairment (OR 2.92, 95% CI 1.01–7.76, p = 0.03), whereas the association with severe DLCO reduction was not statistically significant (p = 0.36).

Discussion

Functional implications of dual pathology

This study demonstrates that the coexistence of emphysema and fibrosis in hypersensitivity pneumonitis (HP) defines a distinct clinical and functional phenotype. These findings are consistent with previous studies highlighting the heterogeneity of HP and the

Table 2. Comparison of HP subtype groups

		Emphysema n = 32				**Fibrosis n =133**				**Combined emphysema and fibrosis n =27**		
		n (%)		**p**		**n (%)**		**p**		**n (%)**		**p**
Age	≤65	17 (53.1)		**0.02**		77 (57.9)		**0.001**		13 (48.1)		**0.001**
	>65	15 (46.9)				56 (42.1)				14 (51.9)		
Sex	Female	8 (25.0)		**0.01**		59 (44.4)		0.15		7 (25.9)		**0.01**
	Male	24 (75.0)				74 (55.6)				20 (74.1)		
Smoking habits	Non-smoker	11 (34.4)		0.07		58 (43.6)		**0.04**		13 (48.1)		**0.001**
	Smoker	21 (65.7)				75 (56.4)				14 (51.9)		

(%) Column percentages. Bold numbers indicate statistical significance (p<0.05). *Abbreviation:* HP: hypersensitivity pneumonitis.

Table 3. Risk of severe pulmonary function impairment in patients with HP

	FVC < 50 OR (95% CI)	**p**	**DLCO < 35 OR (95% CI)**	**p**
Age >65	0.84 (0.33-2.10)	0.70	0.68 (0.21-2.15)	0.51
Sex (Female)	1.18 (0.52-2.65)	0.67	0.85 (0.32-2.24)	0.74
Smoking	0.62 (0.27-1.141)	0.26	1.22 (0.46-3.23)	0.68
Emphysema	**2.86 (1.12-7.25)**	**0.03**	0.31 (0.04-2.43)	0.27
Fibrosis	**3.01 (1.09-8.30)**	**0.03**	**5.40 (1.20-24.14)**	**0.03**
Combined emphysema and fibrosis	**2.92 (1.01-7.76)**	**0.03**	2.60 (0.33-20.35)	0.36

Abbreviations: HP: hypersensitivity pneumonitis, FVC: forced vital capacity, DLCO: diffusing capacity of the lung for carbon monoxide. Bold numbers indicate statistical significance (p<0.05).

influence of demographic factors on disease expression (1,2). Our results indicate that combined emphysema and fibrosis (CE-HP) patients experience significant functional impairment, particularly in terms of forced vital capacity (FVC). Specifically, the presence of combined pathology was associated with a nearly threefold increase in the risk of severe FVC impairment (OR 2.92, p=0.03). A noteworthy finding in our cohort was the impact on gas exchange. Although emphysema extent showed a moderate inverse correlation with DLCO ($r = -0.56$, $p < 0.001$), indicating a substantial contribution of emphysema to gas exchange impairment beyond fibrotic involvement (9,17), the association between the CE-HP phenotype and severe DLCO reduction (<35% predicted) did not reach statistical significance in the logistic regression model ($p = 0.36$). This may be attributed to the relatively small sample size of the CE-HP group or the possibility that fibrotic changes remain the primary driver of severe diffusion impairment in this specific cohort (18,26). These functional patterns resemble those described in combined pulmonary fibrosis and emphysema (CP-FE) associated with other fibrosing interstitial lung diseases, where relatively preserved lung volumes may coexist with disproportionately reduced diffusion capacity (12,16).

Clinical and pathophysiological considerations

The demographic profile of CE-HP patients—predominantly older males with a history of smoking—mirrors the patterns observed in fibrosing lung diseases with emphysematous involvement (12,21). Cigarette smoke likely acts as a common trigger, enhancing oxidative stress and macrophage activation, thereby promoting the coexistence of emphysematous and fibrotic changes (4,19). From a clinical standpoint, recognizing the CE-HP phenotype is vital because traditional spirometric measures can sometimes be misleading (16). Patients with this phenotype may demonstrate relatively preserved spirometric values despite advanced parenchymal damage, emphasizing the importance of DLCO measurement and HRCT evaluation during follow-up (3,6,9). Furthermore, the distinct mechanical and vascular characteristics of this phenotype suggest that these patients might require tailored therapeutic strategies, potentially including antifibrotic approaches extrapolated from other fibrosing interstitial lung diseases (1,14,16). Recognition of CE-HP as a distinct clinical phenotype may facilitate more accurate functional assessment and improve prognostic stratification (12,27).

Study limitations

This study's retrospective design and single-center scope may limit the generalizability of the findings to broader populations. Although the cohort size is substantial for a single center, the relatively small number of patients in the CE-HP subgroup may have limited the statistical power to detect smaller differences in certain gas exchange parameters, particularly regarding the severity of DLCO reduction. Furthermore, while radiological classifications were meticulously performed, the lack of quantitative HRCT analysis and longitudinal functional follow-up represents a limitation in characterizing the progression of this phenotype. Finally, data on pulmonary artery pressures or the presence of pulmonary hypertension were not systematically available, as echocardiographic or invasive hemodynamic assessments were not routinely performed in all patients.

Conclusions

Our findings indicate that the coexistence of emphysema and fibrosis in hypersensitivity pneumonitis (CE-HP) represents a distinct radiological and functional phenotype rather than a coincidental imaging finding. This dual pathology is characterized by a significant functional burden, manifesting as a more pronounced impairment in forced vital capacity and gas exchange compared to non-fibrotic or purely fibrotic presentations. The higher prevalence of older age, male sex, and smoking history among patients with CE-HP suggests that cigarette smoke may act as a critical modifier in the pulmonary fibrotic response. From a clinical perspective, the recognition of CE-HP is essential for accurate patient management. The competing mechanical effects of emphysema and fibrosis may lead to a deceptive preservation of lung

volumes, potentially masking the severity of underlying parenchymal damage. Therefore, clinicians should prioritize the integration of DLCO and HRCT findings over spirometry alone when monitoring these patients. Identifying this phenotype not only facilitates more precise functional assessment and prognostic stratification but also supports the need for individualized therapeutic strategies—such as earlier antifibrotic intervention and rigorous smoking cessation—within the complex spectrum of hypersensitivity pneumonitis.

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Availability of Data and Materials: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Authors' Contributions: FÖE: Conceptualization, Study design, Data curation, Writing – original draft; AÖ: Radiologic review, Data interpretation; BA: Statistical analysis, Methodology; AY: Supervision, Writing – review and editing; ÖG: Clinical data acquisition, Literature review. All authors read and approved the final version of the manuscript.

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