

Association of pulmonary function test patterns with clinical features and laboratory findings in patients with sarcoidosis: a multicenter observational study

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Abstract

Background

Patients with sarcoidosis may demonstrate different pulmonary function test (PFT) patterns, including obstructive and restrictive dysfunction; however, data regarding the clinical significance of these patterns remain limited. This study aimed to compare the clinical features and laboratory characteristics of patients with sarcoidosis according to PFT patterns.

Methods

This multicenter retrospective observational study included 590 patients diagnosed with sarcoidosis in 9 referral centers of our country between January 2015 and April 2023. Patients were classified into normal, obstructive, and restrictive PFT pattern groups according to spirometry. Demographic characteristics, laboratory parameters, radiological stages, and DLCO values at the time of diagnosis, treatment status, and recurrence rates during 2-year follow-up were compared among the PFT groups. Univariable and multivariable logistic regression analyses were performed to identify factors independently associated with PFT patterns.

Results

There was 590 patients and mean age was 49.2, and 69% of them was female. Of the all patients, 359 (60.9%) had normal PFT findings, 139 (23.6%) had obstructive patterns, and 92 (15.6%) had restrictive patterns. Obstructive dysfunction was more common than restrictive dysfunction. Compared with the normal and obstructive groups, patients with restrictive PFT patterns had significantly more advanced radiological stages, lower DLCO values, and higher rates of systemic immunosuppressive treatment. Patients with restrictive patterns were also older and more frequently symptomatic than those with normal PFT findings. In multivariable logistic regression analysis, lower DLCO% values remained independently associated with restrictive PFT patterns both compared with normal PFT patterns (AOR: 0.90, 95% CI: 0.87–0.92) and obstructive PFT patterns (AOR: 0.92, 95% CI: 0.89–0.94).

Conclusions

Patients presenting with restrictive dysfunction at diagnosis may require closer clinical monitoring and follow-up owing to their potentially more severe disease course.

Introduction

Sarcoidosis is a multisystemic inflammatory disease of unknown etiology, predominantly affecting the lungs and intrathoracic lymph nodes (1). While approximately 60–80% of patients experience

spontaneous remission, the remaining 20–40% follow a chronic or progressive clinical course that can culminate in severe fibrosis or organ failure (2).

Impaired pulmonary function at onset has been established as a strong indicator of poor long-term prognosis. Specifically, a baseline carbon monoxide diffusing capacity (DLCO) < 60 or forced vital capacity (FVC) < 70%, as well as a subsequent 5% decline in FVC or a 10% decrease in DLCO during follow-up, are clinically significant markers reflecting disease progression (3). Furthermore, cumulative evidence suggests that pulmonary function tests (PFT) are highly instrumental in predicting disease activity (4–6).

Patients with sarcoidosis may exhibit normal pulmonary function or distinct ventilatory phenotypes, including obstructive, restrictive, and mixed patterns (7). On thoracic computed tomography (CT), interstitial fibrosis is typically associated with a restrictive pattern, whereas airway traction and bronchial stenosis predominantly drive obstructive dysfunction (8). To date, evidence regarding the prevalence of these pulmonary function patterns remains conflicting, with studies reporting either restrictive or obstructive impairment as the dominant abnormality (9, 10, 11). Consequently, it is hypothesised that distinct clinical, laboratory, and radiological phenotypes exist based on these respiratory function profiles. However, comprehensive data characterising sarcoidosis studies according to their specific PFT findings remain scarce (12, 13). Therefore, this study aims to evaluate whether differences in baseline respiratory patterns correspond to distinct demographic profiles, radiological features, laboratory values, treatment requirements, and recurrence rates.

Materials and methods

This multicenter retrospective observational study included 590 patients diagnosed with sarcoidosis in the pulmonary outpatient clinics of 9 training and research hospitals located in our country between January 2015 and April 2023. The coordinating center was the ethics committee hospital, and all participating centers were regional advanced referral hospitals. All sarcoidosis patients included in the initial evaluation were diagnosed according to the American Thoracic Society criteria, which are based on concordant clinical and radiological findings, histopathological demonstration of non-necrotising granulomatous inflammation, and exclusion of alternative granulomatous diseases (14).

Histopathological confirmation demonstrating non-necrotising granulomatous inflammation was available for all patients. Demographic characteristics, laboratory parameters, radiological stages, treatment status, history of recurrence, diagnostic procedures, comorbidities, DLCO, and PFT results were obtained from medical records. The inclusion criteria were: age between 18 and 80 years, at least 2 years of follow-up, availability of complete blood count and biochemical test results at the time of diagnosis (within 1 month before diagnosis or at the first outpatient visit immediately after diagnosis), and ability to perform spirometry and DLCO testing. Patients with known obstructive pulmonary disease prior to diagnosis, active malignancy, advanced organ failure, rheumatological disease, pulmonary parenchymal involvement secondary to causes other than sarcoidosis (e.g., vasculitis or occupational lung disease), or mixed-pattern PFT findings were excluded from the study (n = 106). Symptom was

defined as the presence of respiratory symptoms, including dyspnea and cough, at the time of diagnosis. Recurrence was defined as the activation of the disease following remission or stable disease during the 2-year follow-up period. Treatment status was defined as receiving systemic immunosuppressive treatment due to pulmonary involvement during the 2-year follow-up. Comorbidity was characterised by the existence of additional diseases, such as diabetes mellitus, cardiovascular disease, and hypertension. The neutrophil-lymphocyte ratio (NLR) was calculated by dividing the absolute number of neutrophils by the absolute number of lymphocytes, and the platelet-lymphocyte ratio (PLR) was calculated by dividing the number of platelets by the absolute number of lymphocytes. The primary outcome of the study was the PFT pattern at the time of diagnosis. Four pulmonary function phenotypes were defined according to spirometric findings. Restrictive ventilatory impairment was defined as $FVC < 80\%$ predicted and $FEV1/FVC \geq 80\%$, whereas obstructive ventilatory impairment was defined as $FEV1/FVC < 80\%$ and $FVC \geq 80\%$. Patients with both $FEV1/FVC < 80\%$ and $FVC < 80\%$ were considered to have a mixed ventilatory pattern. Patients who did not meet any of these criteria were classified as having a normal PFT pattern (15). Because total lung volumes were not assessed using body plethysmography, differentiation between pure obstructive ventilatory defects and combined obstructive–restrictive defects within the mixed ventilatory pattern group could not be performed. Therefore, patients with spirometric findings suggestive of a mixed ventilatory pattern were excluded from the study ($n = 43$). The study protocol was approved by the ethics committee of the coordination center in accordance with the Declaration of Helsinki (date: 11.09.2025, approval number: 2024-82). Due to the retrospective design of the study and the use of anonymised patient data, the requirement for written informed consent was waived by the ethics committee.

Statistical Analysis:

Statistical analyses were performed using Jamovi software (version 2.7.28; Jamovi Project, Sydney, Australia). Continuous variables were assessed for normality using the Shapiro–Wilk test and visual inspection of histograms and Q–Q plots. Normally distributed variables were presented as mean $\pm$ standard deviation (SD), and non-normally distributed variables were expressed as median and interquartile range (IQR). Categorical variables were presented as numbers and percentages. Variables with normal distribution were compared among PFT pattern groups using one-way ANOVA, whereas non-normally distributed laboratory variables were analysed using the Kruskal–Wallis test. Categorical variables were compared using the chi-square test. Post-hoc pairwise comparisons after the Kruskal–Wallis test were conducted using Dunn’s test with Bonferroni correction. Univariable logistic regression analyses were performed to evaluate the associations between clinical characteristics and PFT patterns. Variables found to be statistically significant in the univariable analysis, together with the general covariates age and gender, were included in the multivariable logistic regression models. Odds ratios (ORs) and adjusted odds ratios (AORs) were reported with 95% confidence intervals (CIs). A two-tailed p -value < 0.05 was considered statistically significant. Given three pairwise comparisons, a Bonferroni-adjusted p -value < 0.017 was considered statistically significant for post hoc analyses.

Results

In total, 590 patients with sarcoidosis were included in the study. The mean age was 49.24 ± 11.50 years, and 69.15% of the patients were female. The majority of patients were never-smokers (73.56%), symptomatic at diagnosis (83.9%), and had no recurrence of disease (84.9%). According to PFT patterns, 359 patients (60.85%) had normal PFT findings, 139 (23.56%) had an obstructive pattern, and 92 (15.59%) had a restrictive pattern. Most patients were classified as Scadding stage 0–I (47.3%) or stage II (48.3%). The clinical characteristics and the laboratory values are summarised in Table 1 and Table 2. Post-hoc analyses with Bonferroni correction showed that patients with restrictive PFT patterns had higher WBC and neutrophil counts compared with patients with normal PFT patterns. Platelet counts were significantly lower in the obstructive group than in the restrictive groups, whereas albumin levels were lower in the patients with obstructive PFT patterns than in the normal group. Calcium levels differed significantly between restrictive and normal PFT groups, with lower median calcium levels observed in the restrictive group. A significant difference in glucose levels was observed between obstructive and restrictive PFT groups, with higher glucose levels in the obstructive group. No significant differences were observed for lymphocyte count, eosinophil count, NLR, PLR, hemoglobin, urea, creatinine, AST, ALT, ACE and CRP levels. The comparison of laboratory values according to PFT patterns is presented in Table 3. In univariable logistic regression analysis, restrictive PFT patterns were significantly associated with older age (OR: 1.02, 95% CI: 1.01–1.04), presence of symptoms (OR: 2.54, 95% CI: 1.24–5.92), recurrence (OR: 2.12, 95% CI: 1.17–3.75), Scadding stage II (OR: 3.16, 95% CI: 1.90–5.39), Scadding stages III–IV (OR: 4.27, 95% CI: 1.58–10.95), treatment status (OR: 3.31, 95% CI: 2.07–5.33), and lower DLCO% values (OR: 0.90, 95% CI: 0.88–0.92) than the normal PFT group. Compared with the obstructive group, restrictive patterns were positively associated with Scadding stage II (OR: 2.16, 95% CI: 1.22–3.90), stage III–IV (OR: 7.00, 95% CI: 1.86–34.03), and treatment use (OR: 2.49, 95% CI: 1.45–4.30), while lower DLCO% remained significantly associated (OR: 0.92, 95% CI: 0.89–0.94). The results of the univariable logistic regression analyses are shown in Table 4. Multivariable logistic regression analysis demonstrated that lower DLCO% was independently associated with restrictive PFT patterns both in comparison with normal PFT patterns (AOR: 0.90, 95% CI: 0.87–0.92) and obstructive PFT patterns (AOR: 0.92, 95% CI: 0.89–0.94). Other clinical variables, including symptom status, recurrence, radiological stage, and treatment use, were not independently associated after adjustment (Table 5).

Discussion

In our study, normal spirometry was observed in 359 (60.8%) patients at diagnosis, whereas obstructive and restrictive ventilatory impairments were identified in 139 (23.6%) and 92 (15.6%) patients, respectively. Thus, obstructive impairment was approximately 1.5 times more common than restrictive impairment. The predominance of obstructive or restrictive ventilatory defects in sarcoidosis remains controversial. Several studies have reported restrictive impairment as the most common abnormality (12, 13, 15), whereas more recent investigations have identified an obstructive pattern as the predominant ventilatory pattern (16, 17, 18). Mañá et al., in their cohort of 640 patients with sarcoidosis,

found obstructive ventilatory dysfunction to be more common than restrictive dysfunction. They proposed that differences in the FEV1/FVC cut-off values used to define airflow obstruction (70% versus 80%) may contribute to the variability in pulmonary function patterns reported across studies (17). Consistent with this approach, an FEV1/FVC threshold of 80% was used in our study. Harrison et al. found that more than half of the patients with newly diagnosed sarcoidosis had airflow limitations, but restrictive defects were not very common (19). Calaras et al. similarly showed that patients with intrathoracic sarcoidosis had more obstructive patterns than restrictive patterns in PFT (16). Thillai et al. reported that obstructive dysfunction in patients with sarcoidosis is often overlooked in clinical practice, although it may occur as frequently as restrictive dysfunction (10). Furthermore, Sharp et al. demonstrated substantial heterogeneity in pulmonary function phenotypes and reported significant differences according to race and sex, indicating that demographic characteristics may also contribute to the variability observed across studies (12). Vanderhoef et al. similarly suggested that differences in demographic and clinical characteristics, as well as sample size, may explain inconsistent findings between studies (18). Taken together, these findings suggest that airway involvement may represent a major functional manifestation of pulmonary sarcoidosis. The higher prevalence of obstructive impairment in our results may reflect the impact of granulomatous inflammation involving both small and large airways, which can precede the development of extensive fibrotic parenchymal changes.

In our study's univariable analysis results, the restrictive pattern was associated with advanced age, recurrence, presence of symptoms, advanced Scadding stage, and high treatment requirement. Sharp et al. demonstrated a significant decline in both FVC% predicted and FEV1% predicted, particularly FVC%, over a three-year follow-up period among patients with restrictive physiology compared with those with normal lung function. During follow-up, patients with an obstructive ventilatory pattern demonstrated greater improvements in FVC% values than those with normal pulmonary function. Based on these findings, the authors suggested that patients with a restrictive phenotype may require closer clinical monitoring (13). Another study reported that obstructive dysfunction is present in sarcoidosis patients from the early stages and begins to appear along with restriction as the disease progresses (16). Te et al. found that the mean FVC was lower in stage 4 disease compared to other Scadding stages and noted a restrictive pattern in stage 4 (15). In addition, Mañá et al. demonstrated that both obstructive and restrictive abnormalities became more common with increasing radiological stage, although the association appeared stronger for obstructive dysfunction (17). Other studies have also reported similar associations between airflow limitation and radiographic disease severity (20). Consistent with these findings, the ACCESS study reported a higher prevalence of airway obstruction in patients with more advanced radiographic disease (21). The current treatment guidelines for pulmonary sarcoidosis predominantly rely on respiratory functional impairment, radiological anomalies, symptomatology, and indicators of disease progression (22). Patients with moderate-to-severe pulmonary fibrosis and reduced FVC and DLCO values are generally more likely to require treatment (23). Since our patients with restrictive patterns had lower DLCO values, it is to be expected from our study results that they would receive more treatment. Vanderhoef et al. found no significant age differences among patients with normal, obstructive, and restrictive pulmonary function phenotypes (18). In contrast, other studies have

reported a higher prevalence of obstructive physiology among older patients (10). In multivariate analysis, the loss of independence of Scadding radiological stages and treatment status suggests that functional parameters may be more decisive than radiological staging in explaining restrictive ventilatory impairment. Sharp et al. showed that initial functional phenotypes, especially the restrictive pattern, in pulmonary sarcoidosis are closely related to changes in lung function over time (12, 13). In our study, the fact that low DLCO% was the only variable independently associated with the restrictive pattern supports the idea that functional impairment in gas exchange may be one of the key features of the restrictive phenotype. Boros et al. reported that impaired lung compliance and reduced DLCO may be detected in patients with sarcoidosis even in the absence of an overt restrictive ventilatory defect, suggesting that these parameters are sensitive indicators of parenchymal involvement (11). Our findings support the need for clinicians to give absolute priority to DLCO% monitoring rather than conventional parameters in the follow-up of patients with restrictive impairment at the time of diagnosis.

In laboratory parameters, patients with a restrictive PFT pattern had higher WBC and neutrophil counts compared to patients with a normal PFT pattern. This finding suggests that patients with restrictive ventilatory impairment may have a more pronounced systemic inflammatory response. However, no significant differences were found between the groups in terms of ACE and CRP levels, which are frequently used in the assessment of sarcoidosis activity, and inflammatory indices such as NLR and PLR. This is consistent with the findings of Mana et al., which show that biochemical activity markers and functional outcomes may not always be parallel (4). Vanderhoef et al. found CRP to be higher in the restrictive group than in the obstructive group. They reported that there was no difference between the groups in terms of WBC and ACE values (18). Traditional serum biomarkers showed limited utility in differentiating PFT phenotypes in our cohort, indicating that routine laboratory markers may not adequately reflect functional heterogeneity in sarcoidosis.

Our study's strongest features are its multicenter design, the inclusion of a large patient population ($n = 590$) representing nine hospitals of our country, and the availability of histopathological confirmation for all patients. Furthermore, the clear recording of recurrence and treatment statuses by following each patient for at least two years enhanced the prognostic power of our regression models. However, our study has some limitations. Firstly, due to its retrospective design, data extraction from archive records may have resulted in some data loss. Secondly, total lung capacity measurements using body plethysmography, which are crucial for differentiating obstructive and mixed respiratory patterns, could not be performed. Therefore, patients with $FEV_1/FVC < 80$ and $FVC < 80$, where a complete differentiation between obstructive and mixed patterns could not be made, were excluded from the study. However, since the number of patients exhibiting these characteristics was very small, it is believed that this did not affect our study results. Finally, another limitation of this study is that it relied on cross-sectional measurements obtained at diagnosis rather than evaluating longitudinal changes in PFTs and DLCO over the two-year follow-up period.

In conclusion, normal pulmonary function was the most common pattern at diagnosis in patients with sarcoidosis. Among abnormal pulmonary function patterns, obstructive dysfunction was more frequent

than restrictive dysfunction. However, patients with a restrictive PFT pattern represented a clinically less favourable subgroup, characterised by more advanced radiological stages, a higher symptom burden, an increased risk of relapse, and greater immunosuppressive treatment requirements. Multivariable analysis identified low DLCO% as the only independent factor associated with the restrictive phenotype. These findings suggest that sarcoidosis patients presenting with restrictive dysfunction and reduced DLCO at diagnosis may warrant closer clinical monitoring, irrespective of radiological stage.

Abbreviations

PFT

Pulmonary function test

DLCO

Carbon monoxide diffusing capacity

FVC

Forced vital capacity

CT

Computed tomography

NLR

Neutrophil-lymphocyte ratio

PLR

Platelet-lymphocyte ratio

SD

Standard deviation

IQR

Interquartile range

ORs

Odds ratios

AORs

Adjusted odds ratios

CIs

Confidence intervals

Declarations

Ethics approval: The study protocol was approved by the ethics committee of the Health Sciences University, Sureyyapasa Chest Diseases and Thoracic Surgery Training and Research Hospital in accordance with the Declaration of Helsinki (date: 11.09.2025, approval number: 2024-82). Due to the retrospective design of the study and the use of anonymised patient data, the requirement for written informed consent was waived by the ethics committee.

Consent for publication: not applicable.

Availability of data and materials: the datasets used and analysed during the current study are available from the corresponding author on reasonable request

Competing interests: the authors declare no competing interests.

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Authors' contributions:

SAE and TK conceived and designed the study. SAE, MK, DD, FDU, GK, NB, GK, OO, MY, OOD, SD, FK, UT, AAOG, ADD, OS, FY and TK contributed to data collection. OG contributed to statistical analysis. SAE, OG contributed to manuscript writing. All authors contributed to data interpretation, critically revised the manuscript, and approved the final version.

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Tables

Tables 1 to 5 are available in the Supplementary Files section.

Supplementary Files

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