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Study of the prevalence and predictive factors of sleep-disordered breathing in patients with interstitial lung diseases

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Abstract

Background Interstitial lung diseases (ILDs) are parenchymal lung conditions that are chronic, progressive, and have a high morbidity and mortality rate. Due to restrictions in their gas exchange and ventilatory dysfunction, ILD patients are probably at risk for sleep-disordered breathing (SDB).

Methodology Sixty-nine patients with diffuse parenchymal lung diseases identified by high-resolution computed tomography (HRCT) chest were included in the study. All patients were assessed by the STOP-BANG questionnaire (SBQ), Epworth sleepiness scale (ESS), and full-night polysomnography (PSG) for diagnosis and classification of SDB. The aim of the study is to examine the prevalence and risk factors for SDB in ILD.

Results Among the study group hypersensitivity pneumonitis (HP) was the most prevalent ILD, accounting for 63.8% of cases. Out of 69 individuals, 42 (60.9%) had SDB, 57.1% of those with SDB had obstructive sleep apnea (OSA), and the majority of those with OSA had mild degrees (21.7%, $n=15$).

Conclusion OSA is significantly common in ILD patients. Higher left atrium diameter and oxygen desaturation index (ODI) are predictive factors of SDB. To facilitate early diagnosis and therapy, PSG should be performed on ILD patients at high risk (such as males, individuals with high ESS scores, SBQ scores, and left atrium diameter).

Trial registration Retrospectively registered, registration number is NCT06012526, date of registration August 25, 2023.

Keywords Interstitial lung diseases, Sleep disordered breathing, Polysomnography, Pulmonary function

Background

With a variety of clinical outcomes, ILDs are a diverse group of diffuse parenchymal lung diseases [1]. They impact the lung interstitium and alveolar-capillary membrane, which prevent diffusion [2]. Chronic hypoxia and restrictive lung disease with compromised ventilation are the results of this. In the end, they cause pulmonary hypertension, cor-pulmonale, and respiratory failure [3].

Idiopathic pulmonary fibrosis (IPF), the most prevalent type of idiopathic interstitial pneumonia, has a median survival period of 3–4 years [4].

The term SDB refers to a set of conditions where breathing is interrupted while you sleep, either partially or completely. OSA is the most prevalent type. Over the past few decades, SDB prevalence has increased as a result of the rising obesity rate of prevalence, improvements in diagnostic approaches, and population aging [5].

OSA is defined by a recurrent pattern of collapse of the upper airway, obstruction of the airflow, and subsequent awakenings. Repeated bouts of partial or complete respiratory cessation during sleep are linked to it, and these

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episodes are typically followed by oxyhemoglobin desaturation [6]. Due to their limited gas exchange and compromised ventilatory function, SDB is probably a risk for ILD patients [7]. Nocturnal oxygen desaturation (NOD) alone or NOD combined with OSA of different intensities can be included in this SDB in ILD [3].

While some studies found that 88% of ILD patients had OSA [8], others found that the prevalence was only 22 to 28% [3]. Differences in the methods employed to diagnose OSA and score hypopnea events on polysomnography, additionally, patients with a past diagnosis and/or those who are at a high risk of OSA were excluded from several studies, are likely to have an impact on reported prevalence variations [9].

In addition, since patients with IPF had a higher prevalence of OSA than those with other ILDs[10], with a majority of men [11], disparities in ILD diagnoses and the demographic structure of the examined patients may further contribute to the observed variations. The aim of the study is to examine the prevalence and risk factors for SDB in patients with ILD.

Methods

This study is a cross-sectional observational study carried out at Beni-Suef University Hospital, Department of Chest Diseases from December 2020 to May 2022. Eighty cases were recruited for the study, and 11 cases of them were excluded as they did not meet the inclusion criteria. The study included 69 patients of both sexes who were diagnosed as having an interstitial lung disease according to ATS/ERS [1] and either admitted to the chest department in Beni-Suef University Hospital or attended its outpatient clinic.

- Inclusion criteria: Both sexes of clinically stable ILD patients older than 18 who met the ATS/ERS criteria for an ILD diagnosis were involved in the study [1].
- Exclusion criteria: Patients with any anatomic upper airway abnormalities, such as a considerable deviation of the nasal septum, nasal polyps, conchae, or tonsillar hypertrophy, and patients with serious psychiatric illnesses or neurological conditions. Patients who have a history of taking medications that significantly affect sleep, such as benzodiazepines, narcotics, and drugs. Patients with any type of chronic pulmonary disease—aside from ILD—had less than 4 h of total sleep per PSG.

Ethical considerations

The study was approved by the Beni-Suef University Research Ethical Committee; their permission number is FMBSUREC/03112020/Srour. Each patient was given a comprehensive description of the goals of the study before their written informed permission was obtained.

All patients were subjected to the following:

a. Complete history taking includes the patient's age, occupation in detail, medications used, history of smoking or raising birds, and presenting symptoms (including their onset, course, and duration), symptoms of ILD as cough and shortness of breath in addition to the history of sleep pattern especially sleep fragmentation, excessive day time sleepiness, and snoring.
b. Clinical examination: Routine general examination for general signs associated with ILD as arthritis or joint deformity, oral cavity, and neck examination, and anthropometric measurements such as weight and BMI were taken. Local chest examination including inspection, palpation, percussion, and auscultation
c. Epworth Sleepiness Scale (ESS) results [12]
d. STOP-Bang questionnaire [13]
e. Six minute walk test (6MWT) [14]
f. Investigations: ABG, CBC, SGPT, SGOT, bilirubin, urea, creatinine, coagulation profile, blood sugar, Na and K and collagen profile, HRCT chest [15], spirometric testing (flow volume loop) accomplished by Master Screen Jaeger-Hochberg, (Germany PFT No.781040) [16], 2-dimensional transthoracic echocardiography (2D) and PSG using SOMNOtouch TM RESP, SomnomedicGmbh, Germany.

The studied patients were classified based on diagnosis of OSA into two groups: the group with OSA and the group without OSA. The aim of the study is to examine the prevalence and risk factors for SDB in ILD.

Data was collected, coded, and analyzed with the Statistical Package for Social Science (SPSS) software version 22 on Windows 7 (SPSS Inc., Chicago, IL, USA). Along with standard deviations as measures of dispersion and mathematical means as metrics of central tendency, direct descriptive analysis of qualitative data presented as numbers and percentages was also carried out. In each research group, quantitative data was checked for normalcy using the One-Sample Kolmogorov–Smirnov test before being subjected to inferential statistic testing. Quantitative data between two independent groups in unrelated samples were compared using the *t*-test. Using the Mann–Whitney test, two independent groups were compared. Comparing two or more qualitative groups is done using the chi-square test. The bivariate Pearson correlation test was utilized to study the relationship between the variables. To examine the link between quantitative dependent and independent variables and

risk factor detection, several linear regressions were conducted. Statistics were considered to be significant at a p-value of 0.05.

Results

In the present study, the prevalence of OSA (measured as an apnea–hypopnea index (AHI) of > 5) was 34.80%. Increased RERA was found in 33 patients, 24 with OSA, and 9 without OSA (4 cases of them had NOD with increased RERAs, 5 cases had increased RERAs only. Also, 9 cases had NOD only. So 42 (24 OSA, 18 "NOD and RERA") patients out of 69 (60.9%) had SDB (Fig. 1).

The current study included 69 ILD patients; they were classified into two groups: group with OSA and group without OSA. Age, height, and sex between the two groups were statistically significantly different with p-values (0.01, 0.006, 0.04), respectively, although other factors, such as comorbidities, were not statistically different. The radiological pattern and the etiology of the patients did not statistically differ between both groups. With a p-value of 0.05, cases with OSA had a statistically significant increased percentage of patients with moderate FVC impairment. There was lower 6MWD and higher CRP in patients with OSA compared to those without OSA with no statistical significance. However, regarding oxygen status, there was a lower mean SpO_2 on RA and a higher number of patients on home oxygen in patients without OSA than those with OSA. There was a statistically significant lower mean of EF % and higher left atrium diameter with a p-value < 0.05 in cases with OSA, while mean EPASP and number of patients who had dilated right ventricle were more in ILD patients without OSA than patients with OSA but with no statistical significance. Left ventricle impairment was more in the OSA group, but right-side affection was more in patients without OSA (Table 1).

A statistically significant higher mean of ESS and a statistically significant higher percentage of patients who had severe ESS degrees with a p-value less than 0.05 were present in cases with OSA. In the OSA group, there was a statistically larger proportion of patients with high SBQ questionnaire scores (p-value 0.05). There was no statistically significant difference in the two groups' sleep architectures (p-value > 0.05). A larger proportion of severe desaturation and a statistically significant lower level of minimal and average SaO_2 in cases with OSA, as well as a higher level of desaturation (number, biggest, and average), and ODI (Table 2).

AHI score was significantly positively correlated with ODI, ESS scores, SBQ score, and left atrium diameter with a p-value of 0.05. However, there was a statistically significant negative correlation between AHI and minimal oxygen level. Also, there was a negative correlation with 6MWD, FVC, EPASP, and average oxygen yet failed to achieve statistical significance (Table 3).

The significant independent predictors of OSA are left atrium diameter (p-value = 0.022) and ODI (p-value = 0.000) (Table 4).

Discussion

Due to their limited gas exchange and ventilatory dysfunction, patients with ILD are likely to be at risk for SDB [7]. SDB is a group of disorders characterized by excessive disordered breathing patterns throughout sleep. The least severe type is respiratory effort-related arousal (RERA), whereas the more severe types include apnea, hypopnea, and abnormalities in gas exchange [17].

In the present study, the prevalence of OSA (measured as an apnea–hypopnea index (AHI) of > 5) was 34.80%. The patients with OSA were classified into 15 cases mild, 4 cases moderate, and 5 cases severe. ODI (p-value = 0.000) and left atrium diameter (p-value = 0.022) were found to be independent risk factors for OSA in the multivariable analysis.

The underlying mechanisms by which ILD causes OSA are yet not completely understood. There is some evidence, though, that the prevalence of OSA impacts how ILD progresses. Reactive oxygen species, for example, are known to be produced by OSA's nocturnal intermittent hypoxia. ILD deteriorates as a result of the overproduction of these reactive oxygen species, which causes tissue damage and cellular dysfunction [18]. Forced breathing efforts to overcome airflow limitation in OSA may result in recurring tractional injury to the lung's periphery, which is also expected to result in lung damage and aggregate ILD [19].

The NOD in ILD has been theorized as a major cumulative spillover effect of transitory or prolonged daytime hypoxia [20]. This can be caused by a number of contributing variables, including a ventilation-perfusion mismatch, dependent small airway closure, and alveolar hypoventilation, with OSA being a contributing factor in some cases [3].

In the present study, OSA was a common incidence in patients with IPF (53.3%) and sarcoidosis (50%) within the subtypes of ILD. Similar to the current study, Kamgo et al. [21], Pihtili et al. [22], and Mavroudi et al. [10] in their studies, they also found that patients with IPF had a greater incidence of OSA. IPF's severe parenchymal damage, which increases the likelihood of airway collapsibility and may predispose to OSA development, may account for the higher percentage of OSA in IPF patients [23].

In all prior studies, the prevalence of OSA was higher than in the current study, with the exception of Reid et al.'s study [24], which reported a 22.0% prevalence of SDB. However, they all discovered that mild OSA was

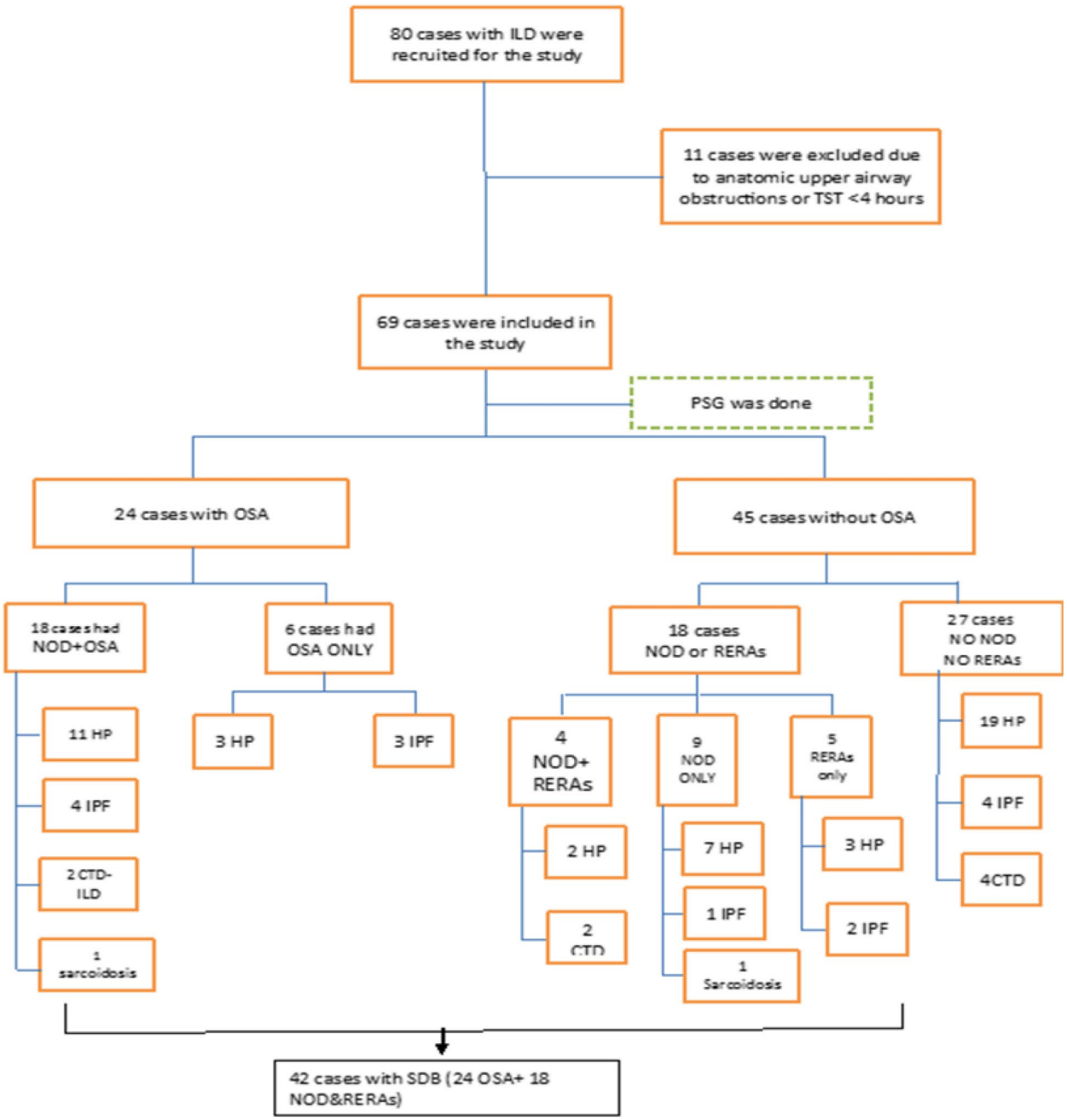

Fig. 1 Flow chart of enrolled patients and distribution of SRBDs among them. *ILD* interstitial lung diseases, *SRBDs* sleep-related breathing disorders, *TST* total sleep time, *PSG* polysomnography, *OSA* obstructive sleep apnea, *NOD* nocturnal oxygen desaturation, *HP* hypersensitivity pneumonitis, *CTD* connective tissue disease, *IPF* idiopathic pulmonary fibrosis, *RERA* respiratory effort-related arousal

the most prevalent form of OSA. This high prevalence of OSA may be caused by distinct subtypes of ILDs. For example, IPF patients were included in the research of Mavroudi et al. [10], Lee et al. [25], and Mermigkis et al. [26], and they were primarily older males with a higher mean age. This may be explained by the features of the patients, who all had IPF and were older, had higher BMIs, and had more co-morbid conditions. Additionally, IPF patients in Saravanan et al.'s [23] study and a male predominance in Reddy's [27] study may help to explain the increased prevalence of OSA they discovered. The other scenarios could result from differences in genetic, socioeconomic, environmental, and demographic factors. Two studies, however,

Table 1 Comparison of both groups regarding baseline features, comorbidities, ABG, PFT, HRCT, and ECHO

Variable	Overall	Without OSA	With OSA	*p*-value
Patient, no	69	45 (65.2%)	24 (34.8%)	
Age (years)	53.1 ± 14.2	50.1 ± 14.5	58.6 ± 12.2	0.01*
Weight (kg)	73.5 ± 19.4	70.5 ± 20.2	79.04 ± 16.7	0.08
Height (cm)	158.4 ± 11.8	155.6 ± 10.7	163.6 ± 12.3	0.006**
BMI (kg/m^2)	29.2 ± 7	28.8 ± 7.2	29.8 ± 6.7	0.6
Neck circumference (cm)	39.1 ± 4.3	38.4 ± 3.8	40.5 ± 4.8	0.07
Sex				
Male	13 (18.8%)	5 (38.50%)	8 (61.50%)	0.04*
Female	56 (81.2%)	40 (71.40%)	16 (28.60%)	
Occupation				
Not working males	3 (4.30%)	2 (66.70%)	1 (33.30%)	0.8
Housewife	43 (62.40%)	29 (67.40%)	14 (32.60%)	
Working	23 (33.30%)	14 (60.90%)	9 (39.10%)	
Smoking/biomass exposure				
Non-smoker	18 (26.10%)	12 (66.70%)	6 (33.30%)	0.1
Smoking	7 (10.1%)	2 (28.6%)	5 (71.4%)	
Biomass exposure	44 (63.8%)	31 (70.5%)	13 (29.50%)	
ABG				
PH	7.4 ± 0.04	7.4 ± 0.05	7.4 ± 0.03	0.3
PaO_2	74.7 ± 12.8	73.8 ± 12.6	76.4 ± 13.3	0.4
$PaCO_2$	39.7 ± 13.1	38.7 ± 13.4	41.6 ± 12.6	0.3
SaO_2%	93.6 ± 3.4	93.4 ± 3.5	93.8 ± 3.3	0.6
CRP	29.9 ± 42.4	25.1 ± 34	38.8 ± 54.5	0.2
Pulmonary function				
FEV1/FVC	73.4 ± 13.9	72.3 ± 14.7	75.6 ± 12.1	0.3
FEV1%	49.3 ± 20	49.4 ± 22.7	49.3 ± 14.1	0.9
FVC%	53.2 ± 22.9	56.4 ± 26.3	47.1 ± 13.1	0.1
SpO_2 on RA	87.1 ± 8.6	86.9 ± 9.6	87.6 ± 6.6	0.7
6MWD (m)	183.4 ± 113.7	193.3 ± 111.8	164.8 ± 117.5	0.3
Interstitial lung disease				
GGO	46 (66.7%)	29 (60.9%)	17 (39.1%)	0.4
Air trapping	27 (39.1%)	18 (66.7%)	9 (33.3%)	0.9
Honeycombing	14 (20.3%)	7 (50%)	7 (50%)	0.2
Reticulations	42 (60.9%)	25 (59.5%)	17 (40.5%)	0.3
Nodular	4 (5.8%)	2 (50%)	2 (50%)	0.6
Cystic	4 (5.8%)	3 (75%)	1 (25%)	1
Possible etiology				
HP	44 (63.8%)	31 (70.5%)	13 (29.5%)	0.3
CTD-ILD	8 (11.6%)	6 (75%)	2 (25%)	
IPF	15 (21.7%)	7 (46.7%)	8 (53.3%)	
Sarcoidosis	2 (2.9%)	1 (50%)	1 (50%)	
Comorbidities				
DM	13 (18.8%)	5 (46.20%)	8 (53.80%)	0.2
HTN	15 (21.7%)	9 (60%)	6 (40%)	0.8
Echo findings				
EF%	66.03 ± 4.9	66.7 ± 4.4	64.3 ± 5.4	0.03*
Lt atrium diameter (mm)	3.4 ± 0.35	3.2 ± 0.31	3.5 ± 0.33	0.001**
EPASP (mmHg)	42.6 ± 23	44.6 ± 25.9	38.8 ± 15.9	0.3

Table 1 (continued)

Variable	Overall	Without OSA	With OSA	*p*-value
Degree of PHT				
No	38 (55.2%)	24 (63.2%)	14 (36.8%)	0.3
Mild (40–50)	9 (13%)	4 (44.4%)	5 (55.6%)	
Moderate (51–60)	11 (15.9%)	8 (72.7%)	3 (27.3%)	
Severe(> 60)	11 (15.9%)	9 (81.8%)	2 (18.2%)	
RT ventricle				
Normal	47 (68.1%)	29 (61.7%)	18 (38.2%)	0.4
Dilated	22 (31.9%)	16 (72.7%)	6 (27.3%)	

BMI body mass index, *PaO_2* partial pressure of oxygen, *$PaCO_2$* partial pressure of carbon dioxide, *SaO_2* oxygen saturation, *CRP* C-reactive protein, *FEV1* forced expiratory volume in first second, *FVC* forced vital capacity, *6MWD* 6-min walk distance, *GGO* ground glass opacification, *HP* hypersensitivity pneumonitis, *CTD* connective tissue disease, *IPF* idiopathic pulmonary fibrosis, *DM* diabetes mellitus, *HTN* hypertension, *EF* ejection fraction, *EPASP* estimated pulmonary artery systolic pressure, *OSA* obstructive sleep apnea, significant *p*-value of 0.05 or less

found that OSA severity was predominately severe. Mermigkis et al. [28] found a 61.0% OSA rate, with 45.0% of their OSA patients having severe OSA. That study, however, was retrospective and only included individuals who had been referred to the sleep lab because there was a strong clinical suspicion that they had OSA. Additionally, Lancaster et al. [29] revealed that 88% of their IPF subjects had OSA diagnoses, and 68.0% of these patients had severe OSA. Also, in a recent study by Yuki Iijima et al. [30], all 33 patients in their study had OSA (mean AHI was 28.6 ± 17.0, with 7 having mild, 13 having moderate, and 13 having severe OSA).

In the current study, with a *p*-value of < 0.05, the OSA group had a statistically higher mean age (58.6 ± 12.2) and height (163.6 ± 12.3). The older age of the OSA group may be related to the higher prevalence of OSA in the elderly, which has been noted in prior studies [31]. The higher anatomical upper airway collapsibility in this age group compared to younger people may be the cause of OSA in the elderly. Additionally, there was a statistically larger percentage of OSA in men (61.5%) compared to women (28.6%), (*p*-value = 0.04). Weight, BMI, and neck circumference were all higher in the OSA group but lacked statistical significance. There was no statistically significant correlation between AHI and BMI ($r = 0.10$, *p*-value = 0.4).

Similar to these findings, Pihtili et al. [22] found that male patients were diagnosed with OSA more frequently than female patients (92.8 and 58.3%, respectively, *p*-value = 0.02). In the same context; in Saravanan et al.'s study [23], patients with OSA were significantly older than those without OSA (*p*-value = 0.031). There was no discrepancy in BMI, baseline FVC, or PaO_2 between ILD patients with and without OSA. Similar to the current study, Gille et al. [8], Yuki Iijima et al. [30], and Aydogdu et al. [32] found no correlation between AHI and BMI in their studies.

Unlike our study, Lee et al.'s [25] study discovered that the OSA group has shown a propensity to have a higher BMI than the non-OSA group. Also, there was only a slight correlation ($r = 0.404$, *p*-value = 0.004) between the BMI and the AHI in Pihtili et al.'s study [22]. In their studies, Kamgo et al. [21], Saravanan et al. [23], Mermigkis et al. [28], and Lancaster et al. [29] also noted a positive correlation between BMI and AHI in the study groups.

In the present study, lower FVC, lower 6MWD, and higher CRP were found in OSA patients than patients without OSA with no statistical significance. Similarly, lower 6MWD and lower mean FVC were found in a study by Utpat et al. [3]. Similar findings were found in studies by Reddy [27], Zhang et al. [33], and Saravanan et al. [23]. The 6MWD and FVC were poorer in ILD patients with OSA than in those without OSA, according to all prior research, but they did not reach a statistical significance as the current study.

In the current study's comparison of the echocardiographic results, cases with OSA had a statistically significant lower mean EF% and higher left atrium diameter (*p*-value 0.05). However, OSA cases and non-OSA did not differ statistically significantly in terms of EPASP, right ventricular size, or PHT levels (*p*-value > 0.05). AHI and left atrial diameter also showed a statistically significant positive correlation ($r = 0.43$, $p = 0.001$), while mean EPASP and number of patients who had dilated right ventricle were more in ILD patients without OSA than patients with OSA but with no statistical significance. On the other hand, PASP was significantly greater in ILD patients with SDB, particularly in those with OSA, according to research by Utpat et al. [3]. Several pathophysiological mechanisms induced by OSA have been suggested to explain why OSA may lead to

Table 2 Comparison of polysomnographic findings and questionnaire between both groups

Variables	Without OSA	With OSA	*p*-value
Patient, no	45 (65.2%)	24 (34.8%)	
ESS score	4.5 ± 3.8	8.5 ± 5.2	< 0.001**
ESS degree			
Normal	41 (70.7%)	17 (29.3%)	0.01*
Mild	2 (40%)	3 (60%)	
Moderate	2 (100%)	0	
Severe	0	4 (100%)	
SBQ questionnaire			
Low	29 (82.9%)	6 (17.1%)	0.005**
Intermediate	13 (52%)	12 (48%)	
High	3 (33.3%)	6 (66.7%)	
Sleep efficiency (%)	71.9 ± 16.5	65.8 ± 20.8	0.2
Sleep latency (minute)	19.6 ± 15.7	13.6 ± 9.1	0.09
REM (%)	19.1 ± 7.8	17.8 ± 7.3	0.5
Stage 1 (%)	15.9 ± 7.6	16.8 ± 7.1	0.6
Stage 2 (%)	49.6 ± 8.7	48.7 ± 8.2	0.7
Stage 3, 4 (%)	15.3 ± 6.2	16.7 ± 6.1	0.4
Arousal	130.6 ± 87.5	141.4 ± 102.8	0.6
Arousal index	28.4 ± 16.6	29.7 ± 21.7	0.8
RERA			
RERA event number	7.8 ± 9	11.2 ± 17.4	0.3
RERA index	1.9 ± 2.4	2.2 ± 2.7	0.7
RDI	4.4 ± 6.8	19.1 ± 14.5	< 0.001
RDI degree			
Mild	7 (33.3%)	14 (66.7%)	0.6
Moderate	1 (20%)	4 (80%)	
Severe	1 (14.3%)	6 (85.7%)	
Minimal SO_2%	83.4 ± 8.8	75.01 ± 11.03	0.001**
Average SO_2%	93.4 ± 3.7	91 ± 4.7	0.02*
Biggest desaturation %	7.8 ± 4.02	12.2 ± 6.6	0.001**
Average desaturation %	4.9 ± 1.1	5.5 ± 1.3	0.03*
Longest desaturation (sec)	73.9 ± 45.2	87.2 ± 44.1	0.2
TST < 90%	16.9 ± 29.9	29.6 ± 36.5	0.1
Number of desaturations	17.7 ± 44.2	63.9 ± 63.9	0.001**
ODI	2.3 ± 3.3	12.9 ± 13.1	< 0.001**
Desaturation degrees			
Mild	9 (50%)	9 (50%)	0.04*
Moderate	4 (50%)	4 (50%)	
Severe	0	5 (100%)	
HR			
Max. HR	114.04 ± 25.2	109.9 ± 22.3	0.5
Mini. HR	61..5 ± 12.4	63.8 ± 13.7	0.5
Average HR	77.5 ± 13.6	80.2 ± 14.9	0.5
PLM	28.8 ± 42.3	38.3 ± 46.7	0.4
PLM number	3.6 ± 5.2	4.8 ± 5.8	0.3
PLM degree			
Normal	35 (66%)	18 (34%)	0.8
Mild	10 (62.5%)	6 (37.5%)	

ESS Epworth sleepiness scale, *SBQ* STOP-BANG questionnaire, *REM* rapid eye movement, *RERA* respiratory effort-related arousal, *RDI* respiratory disturbance index, *TST < 90%* total sleep time with O_2 saturation less than 90%, *ODI* oxygen disturbance index, *HR* heart rate, *PLM* periodic limb movement, significant *p*-value of 0.05 or less

Table 3 Correlation between AHI score and other ILD patient variables

Variables	AHI score		
	r	*p*-value	Sig
Age (years)	0.18	0.1	NS
Height (cm)	0.16	0.2	NS
Weight (kg)	0.13	0.3	NS
BMI (kg/m^2)	0.10	0.4	NS
Neck circumference (cm)	0.11	0.4	NS
ODI	0.62	< 0.001	HS
6MWD (m)	−0.07	0.6	NS
FVC %	−0.18	0.1	NS
ESS	0.31	0.01	S
EPASP (mmHg)	−0.04	0.7	NS
CRP	0.16	0.2	NS
SBQ score	0.28	0.02	S
Minimal O_2	−0.36	0.002*	HS
Average O_2	−0.22	0.06	NS
TST 90%	0.20	0.09	NS
Lt atrium diameter	0.43	< 0.001	HS
SO_2 on RA	0.13	0.3	NS
REM %	0.001	0.9	NS
PLM index	0.23	0.06	NS

AHI apnea–hypopnea index, significant *p*-value of 0.05 or less

cardiovascular disease. Increased sympathetic activity and low-grade inflammation due to intermittent hypoxemia [34], increased intrathoracic pressure during the apneas causing atrial wall stress [35] and endothelial dysfunction [36] are all mediators thought to be involved.

In the present study, we used SBQ for its high sensitivity, so it is good as a screening tool but with low specificity which can be increased when the test is combined with a highly specific ESS questionnaire as recommended by Zhang et al. [33]. In the present study, in cases with OSA, there was a statistically significant higher mean of ESS (*p*-value 0.001) and a statistically significant higher percentage of severe ESS degree and high SBQ questionnaire (*p*-values 0.01 and 0.005, respectively). AHI and ESS scores as well as SBQ scores had a statistically significant positive correlation ($r = 0.31$, p-value $= 0.01$) and ($r = 0.28$, $p = 0.04$). However, in accordance with the findings of Lancaster et al. [29], the ESS scores in a study by Pihtili et al. [22] did not differ between patients with or without OSA nor were they correlated with the AHI in their study.

In the present study, correlation was done for AHI with other variables and showed a statistically significant positive correlation between the AHI score and ODI ($r = 0.62$, p-value 0.001). However, there was a statistically significant negative correlation ($r = -0.36$,

Table 4 Multivariate linear regression analyses to detect the predictors of OSA among cases

Model	Unstandardized coefficients		Standardized coefficients	*t*	Sig
	B	Std. error	Beta		
(Constant)	−24.230	14.971	––	−1.618	0.111
ESS	.215	.263	.086	.820	0.416
LT atrium diameter(mm)	8.480	3.619	.253	2.343	0.022
(SBQ questionnaire)	−.419	.781	−.061	−.537	0.593
Minimum SO_2%	−.010	.134	−.009	−.075	0.940
ODI	.636	.156	.521	4.083	0.000

p-value = 0.002) between the minimal oxygen level and the AHI. Also, a negative correlation with 6MWD, FVC, EPASP, and average oxygen was found but failed to reach a statistical significance. Conflicting information has been reported regarding FVC. These outcomes could be explained by a technical issue. When patients were awake, the pulmonary function tests were administered while they were sitting, whereas the PSG data were collected during sleep when they were lying down. As a result, these tests were not conducted under identical circumstances.

Similarly, Pihtili et al. [22] and Kamgo et al. [21] in their studies found that the AHI showed a statistically significant positive correlation with ODI ($r = 0.883$, p-value = 0.000), (p-value = 0.000, $r = 0.725$), respectively.

The PFT indices FVC, FEV1, DLCO, and TLC did not exhibit any statistically significant correlation with AHI in a study by Kamgo et al. [21]. AHI did, however, have a statistically significant negative correlation (p-value = 0.007, $r = -0.417$) with FEV1/FVC%.

Pihtili et al.'s study [22] found no correlation between pulmonary function measures in their patients and the AHI, supporting the findings of Lancaster et al. [29]. In contrast, Lee et al. [25], in their research, observed that the 6MWD and lung function parameters (DLCO, FVC, FEV1) were higher in OSA patients compared to non-OSA but not statistically significant. Additionally, Mermigkis et al. [28] discovered that AHI was negatively correlated with FEV1 and FVC percentages in their study. They proposed that in this cohort, a considerable impairment in pulmonary function testing might be a predictor of OSA.

In the current study, the explanatory power of various risk factors on AHI scores among ILD cases was examined using the linear logistic regression model analysis. Increased ESS, SBQ, ODI, left atrium diameter circumference, and lower levels of minimal O_2 level were risk factors for OSA in the unadjusted logistic regression analysis. ODI (p-value = 0.000) and left atrium diameter (p-value = 0.022) were found to be independent risk factors for OSA in the multivariable analysis. In contrast to our study, Lee et al. [25] found that older age, higher body weight, male sex, low levels of C-reactive protein, larger neck circumference, IPF diagnosis, and history of diabetes were all significant risk factors for OSA in patients with ILD. Age (p-value = 0.002), body weight (p-value = 0.012), and diabetes mellitus (p-value = 0.019) were found to be independent risk factors for OSA in the multivariable analysis in their study. Additionally, Zhang et al. [33] found that a STOP-BANG score of 3 points or higher (moderate to high score) could aid in the prediction of OSA (OR = 6.29; 95.0% CI, 2.21–17.9; p-value < 0.01). Additionally, Pereira et al. [37] observed that individuals with ILD who are overweight may have a higher chance of developing OSA.

Limitations

Due to the limited sample size and single-center design of this study, the outcomes and statistical correlation may have been impacted. Another limitation is the cross-sectional design's absence of a control group. There were different ILD types included, with one having a lot of patients and the other having few. The severity of OSA was not examined in the study in relation to how ILD was treated.

Conclusions

Patients with ILDs are more likely to have sleep-related breathing disorders predominantly obstructive sleep apnea (out of 69 included ILD patients, 24 had OSA). The IPF subtype of ILD had a higher prevalence of OSA. In individuals with ILDs, high ODI as well as a large left atrium diameter are predictors of OSA.

Abbreviations

AHI	Apnea-hypopnea index
EPASP	Estimated pulmonary artery systolic pressure
ESS	Epworth sleepiness scale
GGO	Ground glass opacification
HP	Hypersensitivity pneumonitis
HRCT	High-resolution computed tomography

ILDs	Interstitial lung diseases
IPF	Idiopathic pulmonary fibrosis
NOD	Nocturnal oxygen desaturation
OSA	Obstructive sleep apnea
PLM	Periodic limb movement
PSG	Polysomnography
RERA	Respiratory effort-related arousal
SBQ	STOP-Bang questionnaire
SDB	Sleep-disordered breathing
SRBDs	Sleep-related breathing disorders
TST	Total sleep time

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Authors' contributions
NL, WA, and MF conceptualized and supervised the research. MF and MS organized the research site and gathered and evaluated the data. All authors contributed to writing the final paper. The final manuscript was read and approved by all writers.

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Availability of data and materials
The data will be accessible to the journal and reviewers from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Written informed consent was obtained from all patients and/or close family in order to participate in the study. The Beni-Suef University medical faculty's ethical committee gave its approval to the study protocol (FMBSUREC/03112020/Srour).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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