Nature and Science of Sleep

Elevate Series

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ORIGINAL RESEARCH

Effects of Metabolic Factors on Left Ventricular Diastolic Function in Patients with Obstructive Sleep Apnea

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Purpose: The effect of metabolic factors on cardiovascular risk in obstructive sleep apnea (OSA) is unclear. This study aimed to investigate the effect of metabolic factors on the left ventricular diastolic function in patients with OSA.

Patients and Methods: This cross-sectional study included a total of 478 patients with OSA from September 2018 to September 2023. After propensity score matching, wherein 193 patients with OSA with metabolic syndrome (MS) were 1:1 matched to patients with OSA without MS by sex and age, data from 386 patients were ultimately analyzed. Furthermore, all patients were divided into mild, moderate, and severe OSA groups according to their sleep apnea-hypopnea index (AHI). Measurements included nocturnal polysomnography, biochemical testing, and transthoracic echocardiography data.

Results: The AHI in the MS group was higher (30.24±21.69 vs 23.19±17.65, p<0.001) and the lowest oxygen saturation at night was lower (77.67±9.23 vs 80.59±9.26, p<0.001) than those in the non-MS group. Additionally, the left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), end-diastolic ventricular septal thickness (IVST), left ventricular end-diastolic posterior wall thickness (LVPWT), left atrial internal diameter (LAD), and E peak to A peak velocity ratio (E/A) in the MS group were higher than those in the non-MS group (P<0.05). The E peak to e' peak velocity ratio (E/e') in the MS group was higher than that in the non-MS group (12.02±3.68 vs 11.13±3.12, P=0.011) and was positively correlated with the diagnosis of MS and metabolic factors (r=0.115, p=0.024; r=0.131, p=0.010, respectively). Patients with five metabolic factors had a significantly higher risk of E/e' elevation than patients in the non-MS group (odds ratio=4.238, p=0.007).

Conclusion: MS may be related to OSA severity and left ventricular diastolic dysfunction. An increase in metabolic factors may increase the risk of diastolic dysfunction. Among metabolic factors, blood pressure may be the most important.

Keywords: metabolic syndrome, obstructive sleep apnea, left ventricular dysfunction

Introduction

Cardiovascular diseases (CVDs) are a major cause of global morbidity and mortality, and obstructive sleep apnea (OSA) plays an important role in CVD.[1,2] Recently, epidemiological studies have reported an OSA prevalence of 23.6%.[3] Considering the increases in the global average age and number of people with obesity, the prevalence of OSA has shown a significant upward trend every year.[4] Presently, there are approximately 176 million patients with OSA in China; among whom, patients with moderate to severe OSA account for approximately 65.52 million.[5]

OSA is a risk factor for CVDs.[6] OSA is caused by complete or incomplete obstruction of the upper airway during sleep, resulting in snoring, apnea, increased intrathoracic negative pressure, hypercapnia, sleep structure disorders, and hypoxemia. OSA is mainly characterized by chronic intermittent hypoxia, which activates the sympathetic nerves

Received: 6 October 2024
Accepted: 30 December 2024
Published: 10 January 2025

through respiratory-sympathetic coupling and leads to cardiac remodeling and dysfunction.[7] Notably, the left ventricular quality is significantly improved after continuous positive airway pressure treatment in these patients.[8]

Metabolic disorders often develop into metabolic syndromes (MS), including central obesity, high triglyceride levels, hyperglycemia, hypertension, and low high-density lipoprotein cholesterol (HDL-C) levels. Studies have shown that hypertension, diabetes, and obesity have adverse effects on heart structure and function. Patients with OSA and MS have a higher risk of CVD occurrence and related mortality.[9,10] Epidemiological statistics suggest that the risk of further diagnosis of MS in the OSA population is 6–9 times higher than that in the general population.[11] At the same time, hypertension, glucose and lipid metabolism disorders, and obesity also aggravate the development of OSA. Metabolic disorders and OSA are closely linked and aggravate each other to a certain extent.

Patients with OSA and MS may also experience left ventricular hypodiastolic function. However, the effect of left ventricular diastolic function in patients with OSA with MS has not been clearly elucidated to date. Whether the level of metabolic factors and the severity of OSA are associated with the degree of left ventricular diastolic dysfunction also remains poorly described.[12–14] Therefore, this observational study aimed to evaluate the effect of MS on left ventricular diastolic function in patients with OSA.

Materials and Methods

Study Participants

All patients were hospitalized in the Second Affiliated Hospital of Fujian Medical University from September 2018 to September 2023; routine biochemical tests, sleep monitoring, and cardiac color ultrasound were performed. In total, 478 patients were diagnosed with OSA. After propensity score matching, data from 386 patients were analyzed.

The exclusion criteria were (1) age <18 years or >80 years; (2) myocardial infarction, severe liver dysfunction, or severe renal insufficiency; (3) sleep monitoring indicating central sleep apnea syndrome or mixed sleep apnea syndrome; (4) hypertrophic cardiomyopathy, dilated cardiomyopathy, cardiac valve disease, pericarditis, or restricted cardiomyopathy; (5) history of cardiac surgery; (6) bedside cardiac ultrasound examination; (7) patients with other diseases that may affect left ventricular diastolic function; and (8) lack of anthropometric data or other metabolic component data.

OSA was diagnosed based on polysomnography (PSG) findings, with an apnea-hypopnea index (AHI) ≥5 times /h and mainly obstructive events. MS was defined according to the latest diagnostic criteria for MS in China, which was issued by the Chinese Diabetes Society in 2020.[15] Based on these criteria, patients were diagnosed with MS if they met three or more of the following five components: (1) waist circumference ≥90 cm in men and ≥85 cm in women; (2) fasting plasma glucose (FPG) ≥6.1 mmol/L, 2-h plasma glucose ≥7.8 mmol/L, and/or diagnosed with and receiving treatment for diabetes; (3) blood pressure ≥130/85 mmHg and/or diagnosed with and receiving treatment for hypertension; (4) fasting triglycerides (TG)level ≥1.7 mmol/L; and (5) fasting HDL-C level <1.04 mmol/L.

This study was approved by the Ethics Committee of the Second Affiliated Hospital of Fujian Medical University. The study complied with the Declaration of Helsinki (Ethics Approval [2023] No. 639), and all patients signed an informed consent form before information collection and sampling.

Sample Size Determination

To determine the required sample size, the following formula, applicable for cross-sectional studies, was applied: $(Z\alpha/2)2 \times p(1\text{-}p)/d^2$, assuming a 95% confidence interval, prevalence rate (p) of 23.6%, and error rate (d) of 5%. To account for 20% loss to follow-up, 346 patients needed to be recruited. Finally, 478 patients were recruited, and 386 were included in the study after propensity score matching.

Study Population

Patients with OSA were included according to the results of the sleep respiratory screening test. Overall, there were 275 patients with OSA with MS and 203 patients with OSA without MS were initially included. According to the nearest neighbor matching method, 193 patients with MS and 193 without MS were included in the MS and non-MS groups,

respectively. In addition, patients with OSA were divided into mild, moderate, and severe groups according to the results of the sleep respiratory screening.

Biometric Data and Blood Tests

Basic data on sex, age, height, weight, history of hypertension, diabetes, and systolic blood pressure (SBP), diastolic blood pressure (DBP), FPG, TG, and HDL-C levels were collected from all included patients.

Overnight Sleep Study

Nocturnal PSG was performed by senior respiratory physicians, who were not involved in the enrollment and grouping of patients, using a portable PSMS monitor (model NOX A1, Nox T3, and sleep monitor ApneaLink Air).

According to China's Multidisciplinary Diagnosis and Treatment Guidelines for Adult Obstructive Sleep Apnea and the American Academy of Sleep Medicine (AASM) 2012 interpretation rules, the severity of OSA can be categorized based on the AHI into snoring (AHI <5/h), mild (5/h< AHI <15/h), moderate (15/h< AHI <30/h), and severe (AHI ≥30/h) OSA.[16] Based on the lowest minimum oxygen saturation ($LSpO_2$), patients were divided into mild hypoxemia (85% to 90%), moderate hypoxemia (80% to 84%), and severe hypoxemia (<80%).

Echocardiographic Study

Cardiac color Doppler ultrasound was performed by a senior physician using a color Doppler ultrasound diagnostic instrument (model GE VIVIDE95). The left lateral decubitus position was assumed to assess the left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), end-diastolic ventricular septal thickness (IVST), posterior wall thickness of the left ventricular end-diastolic diameter (LVPWT), and left atrial diameter (LAD). Peaks E and A were measured in the mitral valve. The peak velocity ratio of peak E to peak A (E/A) and that of peak E to peak e' (E/e') were also collected. All echocardiographic analyses were performed according to the most recent EACVI/ASE cardiac chamber quantification recommendations from 2015, and cutoffs for abnormalities were also defined in accordance with these recommendations.[17]

Statistical Analysis

Statistical analyses were performed using SPSS software version 26.0 (IBM corp., Armonk: NY). The data were tested for normal distribution and homogeneity of variance. Due to the large sample size, a P-P plot was created and confirmed the data conformed to a normal distribution. The nearest neighbor matching method was used to adjust for the effects of sex and age to achieve 1:1 propensity score matching. Briefly, MS and non-MS served as the grouping variables, while sex and age were input as potential confounding factors to be matched. Data are expressed as the mean ± standard deviation (x ± s). A *t*-test, analysis of variance, and LSD post-hoc test for multiple comparisons were conducted. The correlation between MS and left ventricular diastolic function was analyzed using Pearson's correlation coefficient. The chi-squared test was used to test for associations between different categorical data, and a risk analysis of the correlation between categorical data was conducted. Risk factor data are expressed as percentages using binary logistic regression analysis for bivariate outcomes. $P<0.05$ was considered statistically significant.

Results

Description of the Study Population

We analyzed data from all 478 patients with OSA. A total of 193 patients with OSA with MS were 1:1 matched to patients with OSA without MS by sex and age. After matching, there were statistical differences between the MS and non-MS groups in SBP, DBP, BMI, and TG, HDL-C, and FPG levels ($P<0.05$) (Table 1).

Association Between MS and OSA

A higher AHI and lower $LSpO_2$ were observed in the MS group than in the non-MS group ($P<0.05$) (Table 2). The MS group comprised fewer patients with mild OSA and more with severe OSA (Table 3) relative to the non-MS group.

https://doi.org/10.2147/NSS.S497970

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Table 1 Baseline Data Comparison Between the MS and Non-MS Groups[n (%) or[$\bar{x} \pm s$]

Baseline Data	Before Matching				After Matching*			
	MS	non-MS	t/χ2	p	MS	non-MS	t/χ2	p
N	267	198			193	193		
Age	49.14±12.69	52.29±13.02	−2.655	0.008	51.59±12.76	51.77±12.93	−0.135	0.893
Gender (Male/Female)	220 (80.00) /55 (20.00)	147 (72.40) /56 (27.60)	−3.770	0.052	141 (73.10) /52 (26.90)	141 (73.10) /52 (26.90)	0	1
SBP/DBP (mmHg)	164.44±21.65/96.73±16.536	156.95±25.35/96.73±16.536	3.477/3.396	0.001/0.001	165.61±21.85/101.76±12.26	156.92±25.39/96.62±16.45	3.603/3.480	<0.001/0.001
BMI (kg.m-2)	29.66±4.38	26.05±4.40	8.878	<0.001	29.58±4.58	26.07±4.44	7.648	<0.001
TG (mmol. L-1)	2.71±2.22	1.48±0.90	7.423	<0.001	2.57±2.29	1.49±0.91	6.105	<0.001
HDL-C (mmol. L-1)	0.94±0.23	1.21±0.31	−11.248	<0.001	0.96±0.24	1.21±0.29	−9.481	<0.001
FPG (mmol. L-1)	7.15±2.72	5.67±1.43	7.049	<0.001	7.22±2.78	5.64±1.37	7.090	<0.001

Notes: Statistical methods: Data were reported as the mean (SD) or median (IQR: Q1-Q3). The *t*-test or Mann–Whitney *U*-test or x2_test was used for comparisons between MS group and non-MS group. *After propensity score matching, adjust for 1:1 tendency score matching by age and sex.

Abbreviations: n, number of patients; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; FPG, fasting plasma glucose.

Table 2 Comparison of AHI and LSpO2 Between MS and Non-MS Groups [$\bar{x}\pm s$]

	MS	Non-MS	t	p
N	193	193		
AHI (events/h)	30.24±21.69	23.19±17.65	3.481	<0.001
LSpO2 (%)	77.67±9.23	80.59±9.26	−3.106	<0.001

Notes: Statistical methods: The *t*-test was used for comparisons between MS group and non-MS group.
Abbreviations: n, number of patients; AHI, apnea-hypopnea index; LSpO2, the lowest oxygen saturation.

Table 3 Comparison of the Diagnosis Rates of Different OSA Severity in the MS and Non-MS Groups [n (%)]

	MS	Non-MS	χ2	p
N	193	193		
Mild	56 (29.00)	81 (42.00)	9.843	0.007
Moderate	54 (28.00)	56 (29.00)		
Severe	83 (43.00)	56 (29.00)		

Notes: Statistical methods: The x^2-test was used for comparisons between MS group and non-MS group.

Association Between MS and Left Ventricular Diastolic Function

LVEDD, LVESD, IVST, LVPWT, LAD, A, E/e ‘, and E/A were higher in the MS group than in the non-MS group (P<0.05), whereas E was not statistically different between the two groups (P> 0.05) (Table 4).

Association Between OSA Severity and Left Ventricular Diastolic Function

LVPWT in the severe OSA group was significantly higher than that in the mild and moderate OSA groups (P<0.05), while LVPWT was significantly lower in the mild group than in the moderate OSA group (P<0.05) (Table 5).

Table 4 Comparison of Left Ventricular Diastolic Function Index Levels Between MS and Non-MS Groups [$\bar{x}\pm s$]

	MS	Non-MS	t	p
N	193	193		
LVEDD (mm)	47.61±4.04	46.70±3.87	2.266	0.024
LVESD (mm)	31.04±33.55	30.08±3.45	2.690	0.007
IVST (mm)	11.81±1.61	11.09±1.36	4.756	<0.001
LVPWT (mm)	11.38±1.48	10.75±1.26	4.511	<0.001
LAD (mm)	38.26±4.06	36.39±3.74	4.715	<0.001
E (m/s)	65.93±14.51	67.36±14.69	−0.959	0.338
A (m/s)	79.48±16.97	75.95±16.40	2.077	0.038
E/e’	12.02±3.68	11.13±3.12	2.553	0.011
E/A	0.86±0.27	0.93±0.31	−2.307	0.022

Notes: Statistical methods: The *t*-test was used for comparisons between MS group and non-MS group.
Abbreviations: n, number of patients; LVEDD, the left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; IVST, end-diastolic ventricular septal thickness; LVPWT, left ventricular end-diastolic posterior wall thickness; LAD, left atrial internal diameter.

https://doi.org/10.2147/NSS.S497970

Table 5 Comparison of Different OSA Severity Groups with Left Ventricular Diastolic Function Index Levels [$\bar{x}\pm s$]

	Mild	Moderate	Severe	F	p	Post-Hoc Multiple Comparisons		
N	137	110	139			Group compare	Mean difference	p
LVEDD (mm)	46.82±3.83	47.53±4.21	47.19±3.92	0.983	0.375			
LVESD (mm)	30.33±3.37	30.63±3.79	30.74±3.49	0.496	0.609			
IVST (mm)	11.23±1.39	11.58±1.78	11.58±1.42	2.361	0.096			
LVPWT (mm)	10.82±1.32	11.19±1.60	11.21±1.31	3.179	0.043	Mild vs Moderate	−0.366	0.042
						Moderate vs Severe	−0.018	0.921
						Mild vs Severe	−0.384	0.024
LAD (mm)	36.82±3.19	37.17±4.71	37.94±4.093	2.814	0.061			
E (m/s)	68.50±13.25	65.98±15.02	65.35±15.42	1.774	0.171			
A (m/s)	77.42±16.50	77.76±18.20	77.96±15.91	0.036	0.965			
E/e'	11.46±3.32	11.74±3.44	11.55±3.55	0.200	0.819			
E/A	0.92±0.28	0.89±0.32	0.87±0.29	0.979	0.377			

Abbreviations: n, number of patients; LVEDD, the left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; IVST, end-diastolic ventricular septal thickness; LVPWT, left ventricular end-diastolic posterior wall thickness; LAD, left atrial internal diameter.

Table 6 Left Ventricular Diastolic Function Correlation Analysis 1

	LVEDD		LVESD		IVST		LVPWT		LAD	
	r	p	r	p	r	p	r	p	r	p
BMI (kg.m-2)	0.248	<0.001	0.242	<0.001	0.242	<0.001	0.238	<0.001	0.240	<0.001
SBP (mmHg)	0.177	<0.001	0.194	<0.001	0.447	<0.001	0.435	<0.001	0.187	<0.001
DBP (mmHg)	0.218	<0.001	0.222	<0.001	0.415	<0.001	0.384	<0.001	0.220	<0.001
TG (mmol. L-1)	0.056	0.272	0.044	0.388	−0.032	0.532	−0.048	0.347	−0.013	0.796
HDL-C (mmol. L-1)	−0.024	0.642	−0.052	0.311	−0.051	0.317	−0.035	0.493	−0.065	0.200
FPG (mmol. L-1)	0.037	0.472	0.050	0.330	0.016	0.749	0.015	0.762	0.004	0.944

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; FPG, fasting plasma glucose.

Relationship Between MS Factors and Left Ventricular Diastolic Function

BMI, SBP, and DBP levels were positively associated with LVEDD, LVESD, IVST, LVPWT, and LAD (P<0.001) (Table 6). SBP, DBP, and FPG levels were positively associated with the A level (P<0.05). SBP and FPG levels were positively associated with the E/A ratio, while SBP and DBP levels were positively associated with the E/e' ratio (Table 7). The diagnosis of MS and metabolic factors had a significant positive correlation with the E/e' level (r=0.115, p=0.024; r=0.131, p=0.010, respectively) (Table 8).

Comparison of the Factors Affecting the E/E'

E/e' was significantly different between the MS and non-MS groups (Tables 4 and 8). Receiver operating characteristic (ROC) curves were used to calculate the E/e' Youden index, of 10.5 (Figure 1). According to this index, patients in both groups were divided into the low E/e' (E/e' ≤10) and the high E/e' (E/e' >11) groups. We investigated the metabolic factors among patients with MS and found that SBP and DBP levels were significantly higher in the high E/e' group (P<0.05), whereas BMI, TG, HDL-C, and FPG levels, AHI, and $LSpO_2$ levels were similar compared with the low E/e' group (P>0.05) (Table 9).

Table 7 Left Ventricular Diastolic Function Correlation Analysis 2

	A		E/A		E/e'	
	r	p	r	p	r	p
BMI (kg.m-2)	0.005	0.921	0.028	0.588	−0.004	0.938
SBP (mmHg)	0.164	0.001	−0.089	0.081	0.321	<0.001
DBP (mmHg)	0.117	0.021	−0.001	0.987	0.248	<0.001
TG (mmol. L-1)	−0.008	0.879	0.035	0.497	−0.047	0.352
HDL-C (mmol. L-1)	−0.009	0.865	0.032	0.525	−0.016	0.747
FPG (mmol. L-1)	0.105	0.039	−0.128	0.012	0.037	0.473

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; FPG, fasting plasma glucose.

Table 8 Correlation Analysis of Metabolic Factors of E/E'

	E/e'	
	r	p
MS	0.115	0.024
MS factor	0.131	0.010

Risk Analysis of MS Factors for Elevated E/E'

To clarify whether MS is a risk factor for elevated E/e', we performed univariate analysis and found that, compared with the non-MS group, the MS group had an increased risk of elevated E/e' [odds ratio (OR)=1.568; p=0.039]. In patients with MS, with the accumulation of MS factors, the incidence of elevated E/e' gradually increased. All patients with MS had a higher incidence of E/e' elevation than those without MS. The risk of an elevated E/e' was significantly higher in patients with five MS factors (OR=4.238, p=0.007) (Supplementary Table 1.1).

Discussion

The study showed that patients with OSA with MS had a higher AHI, lower $LSpO_2$ level, more sleep apnea, and lower night minimum oxygen saturation than those without MS. Further, these parameters were more severe in the MS group. This suggests that MS is closely associated with OSA severity. A cohort study with a mean follow-up of 6 years also showed that the proportion of patients with moderate-to-severe OSA with MS was 2.5 times higher than that in patients without MS.[16] When patients have both MS and OSA, the synergy between the two diseases may result in a higher risk of CVD.[18]

Our results also showed that patients with moderate-to-severe OSA had a higher LVPWT than those with mild OSA (Table 5). Whereas the E/e' and E/A ratios—objective indicators of left ventricular diastolic function—were not significantly different between these groups. A systematic review with meta-analysis also showed that patients with OSA were more prone to left atrial expansion, and left ventricular hypertrophy and expansion, while they had no significant changes in diastolic function, which was consistent with the results of the current study.[19,20] This suggests that the severity of OSA may cause changes in cardiac anatomy related to left ventricular diastolic function, although is not sufficient to affect left ventricular diastolic function. Furthermore, the present study found that LVEDD, LVESD, IVST, LVPWT, LAD, and E/e' were higher in patients with OSA with MS than in controls. The risk of elevated E/e' was increased by 56.8% in patients with OSA with MS (Supplementary Table 1.1). After adjusting for the AHI and $LSpO_2$ level, the risk of elevated E/e' increased by 61.9% (Supplementary Table 1.2), suggesting that MS may effect both

https://doi.org/10.2147/NSS.S497970

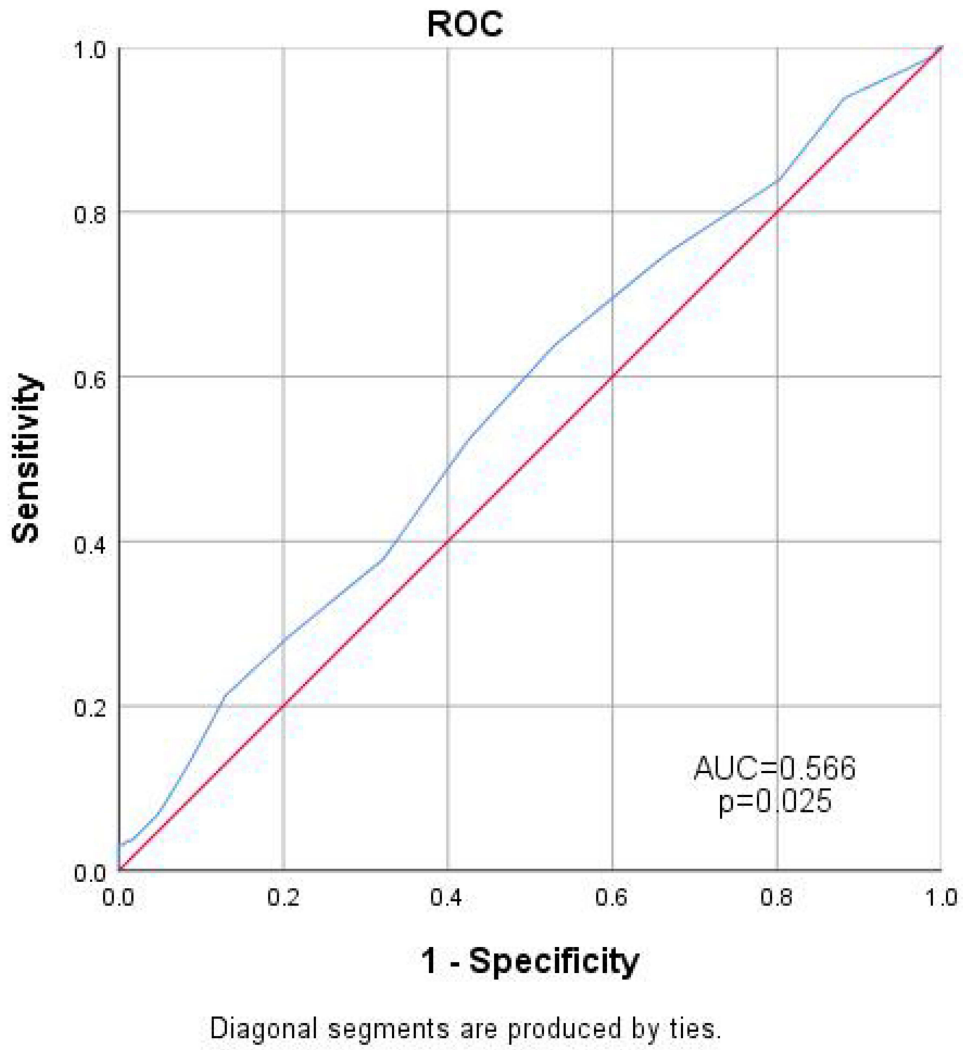

Figure 1 ROC curves were used to calculate the E/e' Youden index, AUC=0.566, p=0.025.

structural changes in the left ventricle and abnormal left ventricular diastolic function in patients with OSA. Therefore, our findings suggest that MS may be an independent risk factor for left ventricular diastolic dysfunction.

In our correlation analyses, we found that the number of metabolic disorder factors was positively correlated with the E/e' level. When the number of MS factors increased to 3–4, the risk of E/e' elevation increased; however, there was no significant difference. When the number of MS factors increased to 5, the risk of E/e' elevation was the greatest and statistically significant. This suggests that a greater presence of metabolic disorder factors may increase the tendency for left ventricular diastolic function decline. Previous studies have also found that the MS factor number is associated with poor prognosis in CVD, in which the effect of MS on left ventricular diastolic function may play an important role.[6]

To further investigate the risk factors for elevated E/e', we calculated the ROC curve and Youden index of E/e'. The results showed that SBP and DBP levels were significantly associated with a higher E/e'. Specifically, the SBP level was identified as an independent risk factor for E/e' elevation, and the E/e' was increased by 3.1% for each unit increase in the SBP level. The previous difference in SBP was 20 units for each grade of hypertension; therefore, left ventricular diastolic abnormalities may increase by 62% with increasing hypertension grade, suggesting that SBP may be an important risk factor for left diastolic dysfunction in patients with OSA (Supplementary Table 2). Previous studies have also demonstrated that OSA and MS can affect left ventricular diastolic function. Consistent with the results of our current study, hypertension has been identified as an important risk factor.[21–23]

Table 9 Comparison of Influencing Factors Between Different E/E' Groups [$\bar{x} \pm s$]

	Low E/e' Group (n=161)	High E/e' Group (n=225)	t	p
SBP (mmHg)	152.80±22.19	167.33±23.55	−6.124	<0.001
DBP (mmHg)	95.30±15.32	101.97±13.63	−4.413	<0.001
BMI (kg·m-2))	27.79±5.40	27.86±4.40	−0.144	0.886
TG (mmol·L-1)	2.09±1.89	1.99±1.78	0.487	0.626
HDL-C (mmol·L-1)	1.09±0.29	1.08±0.29	0.254	0.800
FPG (mmol·L-1)	6.24±1.97	6.56±2.55	−1.335	0.183
AHI (events/h)	26.91±20.23	26.54±19.97	0.178	0.859
LSpO2 (%)	78.84±10.35	79.34±8.57	−0.515	0.607

Notes: Statistical methods: The *t*-test was used for comparisons between Low E/e' group and High E/e' group.
Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; FPG, fasting plasma glucose; AHI, apnea-hypopnea index; LSpO2, the lowest oxygen saturation.

This study has some limitation. Considering the nature of cross-sectional studies, the causal relationships between the variables could not be determined; only the associations between variables could be revealed. Further, the patient sampling strategy may have created bias in the study results. The patients were limited to those hospitalized in our hospital, and the conclusions may not be applicable to populations in other regions. Therefore, it may be necessary to design a more rigorous and widely applicable multicenter, prospective study. In addition, we analyzed the ROC curve of the E/e' index to determine diastolic function. However, in clinical practice, we often apply E/e' <8 to preliminarily judge diastolic function as normal and E/e' >14 as diastolic dysfunction. When 14> E/e' ≥8, other indicators and clinical

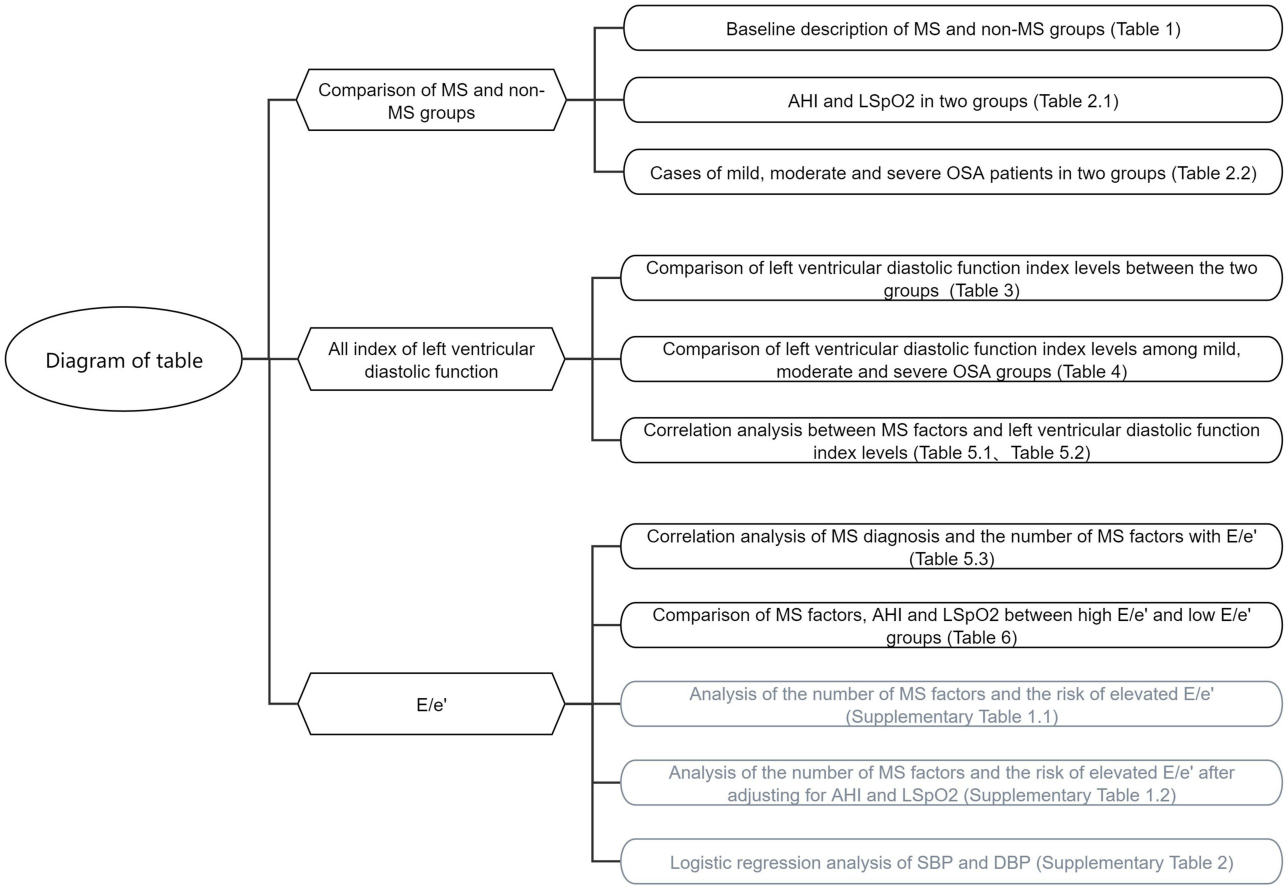

Figure 2 All diagram of table covered in the article. The grey part of the table is shown in the Supplementary Material.

https://doi.org/10.2147/NSS.S497970

conditions, such as E/A and mitral valve E/left atrial volume index, may need to be satisfied for diagnosis. Therefore, more detailed clinical data are needed in future studies to obtain suitable results for clinical practice. Moreover, because most patients without OSA did not undergo PSG in this study, the number of cases with complete information was significantly insufficient to comprise a non-OSA control group. Studies have confirmed OSA an independent risk factor for MS; therefore, we cannot completely isolate the effect of OSA on MS.[18,24] Data of patients with CPAP were insufficient to be included. Some studies have shown that CPAP has obvious benefits for patients with OSA with or without MS; the reversibility of MS was higher after CPAP treatment and left ventricular systolic function was increased in CPAP-treated patients.[25–28] Hence we will further study this group of patients in the future. Finally, we did not control for the use of medications, which might have affected our results to a certain extent. We only evaluated the factors for which medications may have been used to treat, such as blood pressure, blood glucose, and blood lipid levels, and attempted to clarify the relationship between these variables and the left ventricular diastolic function.

Conclusion

MS may be related to OSA severity. Patients with OSA with MS may have more severe disease and more obvious left ventricular structural changes and diastolic dysfunction. MS may be a possible risk factor for left ventricular diastolic dysfunction in patients with OSA. The presence of multiple metabolic factors may aggravate the risk of left ventricular diastolic dysfunction. Among these metabolic factors, blood pressure may be the most important. Nonetheless, more studies are needed to confirm this conclusion.

To summarized, most of the conclusions obtained in this study are presented in tables. Therefore, these tables should be condensed and drawn into graphs for better understanding (Figure 2).

Ethics Approval and Consent to Participate

The present study was conducted in strict accordance with the Declaration of Helsinki and its later amendments or comparable ethical standards. Our research project was approved by the Second Affiliated Hospital of Fujian Medical University ([2023] No. 639).

Acknowledgments

We acknowledge Dr. Yue-Ting Li for providing funding support and thesis writing advisor. We acknowledge the participants for their continued cooperation with this trial. We would like to thank Editage (www.editage.cn) for English language editing.

Funding

This study was supported by the Fujian Provincial Natural Science Foundation (2022J01789) and the Quanzhou High-level Talent Project (2022C032R, 2023C013YR), and funded by the Second Affiliated Hospital of Fujian Medical University PHD Project Foundation (2021GCC08, 2022DB0801, 2022DB0802, 2022DB0803, 2022DB0804).

Disclosure

The authors report no conflicts of interest in this work.

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