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ORIGINAL ARTICLE

The positional characteristics of patients with obstructive sleep apnea: a single institute retrospective study in Japan

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Abstract

Obstructive sleep apnea (OSA) causes sleep-disordered breathing (SDB) due to upper airway obstruction. The severity of OSA changes with position during sleep. Patients with marked significant improvement in apnea–hypopnea index (AHI) level by sleep position change are defined as ''positional patients'' (PP), while those without improvement are defined as ''non-positional patients'' (NPP). We aimed to verify their clinical characteristics. Between May 2008 and May 2020, 237 patients with OSA were registered retrospectively and classified into two groups: PP ($n=158$) and NPP ($n=79$). The differences in clinical background and full-night polysomnography (PSG) between the two groups were observed. A logistic regression analysis was conducted to identify the risk factors for severe AHI (≥ 30 events/h) in the PP group. Moreover, confounding factor-adjusted sub-analysis by a propensity score matching method was performed, and the PSG results were compared between the two groups. The PP group was older than the NPP group. Furthermore, the PP group had lower body mass index (BMI) and AHI levels compared with the NPP group. The independent risk factors for severe AHI in the PP group were BMI and being in the supine position during sleep. The PP group had a significantly milder nocturnal hypoxemia despite having no significant difference in AHI levels between the two groups. The characteristics of PP were old age, low BMI, and low AHI associated with milder nocturnal hypoxemia. Moreover, they were less likely to worsen with nocturnal hypoxemia compared with NPP having similar severity.

Keywords Obstructive sleep apnea · Sleep position · Positional patients · Nocturnal hypoxemia

Introduction

Obstructive sleep apnea (OSA) is a disease that causes sleep-disordered breathing (SDB), such as apnea and hypopnea, which can lead to intermittent hypoxemia and increased sympathetic nerve activity. OSA results in daytime sleepiness and increased risk of cardiovascular and metabolic disorders [1, 2]. It is diagnosed based on the total number of SDB per hour, which is defined as apnea–hypopnea index (AHI). The AHI is measured by full-night polysomnography (PSG).

An epidemiological review reported that OSA had a prevalence of 14% in men and 5% in women [3]. The main pathology of OSA is upper airway stenosis, which can migrate with position changes during sleep [4]. In general, AHI worsens in the supine sleep position and improves in the lateral sleep position. This may be due to the narrowed upper airway influenced by gravity acting on the soft tissue of the pharynx in the supine position. On the other hand, the lateral position can suppress the influence of gravity. Therefore, positional therapy, which corrects the sleep position of the patient to the lateral sleep position, is useful for patients whose AHI levels are significantly reduced by position change from supine to lateral [5, 6]. Cartwright et al. defined ''positional patients'' (PP) as OSA patients in whom the AHI level was at least twice as high in the supine sleep position as in the lateral sleep position [4], while those without a change in AHI level was defined as ''non-positional patients'' (NPP). In a large-scale study involving 574 patients with OSA, the characteristics of PP and NPP were compared [7]. The PP group had lower body mass index (BMI) and AHI level associated with milder nocturnal hypoxemia compared with those in the NPP group. Furthermore, it was hypothesized that fat deposition around the pharynx in obese patients with a high BMI could cause

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upper airway stenosis, which was more difficult to relieve by posture change than stenosis caused by an abnormal skeleton structure. As a result of ineffective posture change, NPP tends to have a higher AHI level than PP. Although some reports had already compared PP and NPP [4, 7], we hereby aimed to verify them in more detail and report new findings.

Materials and methods

Participants

Between May 2008 and May 2020, 336 participants with suspected sleep apnea syndrome underwent full-night PSG at our hospital, and 286 patients with an AHI level ≥ 5 events/h were diagnosed with OSA. Among them, we selected patients who slept for more than 30 min in both the supine and lateral positions and those with oxygen saturation (SpO_2) > 90% (room air) when awake. Consequently, 237 patients were retrospectively enrolled. We divided the 237 patients into two groups (Fig. 1). The PP group ($n = 158$) was consisted of patients with more than two-fold improvement in AHI level when they changed their sleep position from supine to lateral. Contrastingly, the NPP group ($n = 79$) was comprised of patients without more than two-fold improvement in AHI level when they changed their sleep position from supine to lateral.

The patients' clinical backgrounds and the results of their full-night PSG were compared between the two groups. A logistic regression analysis was performed to determine the independent risk factors for severe AHI (≥ 30 events/h) in the PP group. Moreover, we performed an additional sub-analysis that adjusted for confounding factors using a propensity score matching method and compared the results of PSG between the two groups.

Our study was approved by the Research Ethics Committee of Shinshu University School of Medicine (approval number: 5008). The study protocols were performed according to the principles outlined in the Declaration of Helsinki of the World Medical Association.

Diagnosis of OSA

Participants were attached to a PSG device from 9:30 PM (lights off) to 6 AM (lights on). The full-night PSG examination was performed using Alice3 (Philips, Amsterdam, Netherlands), which collected data, including findings from a four-channel electroencephalogram (C4/A1, C3/A2, O2/A1, O1/A2), two-channel electrooculogram, submental and leg electromyogram, airflow (thermistor and pressure transducer), respiratory effort (chest and abdominal movement), oxygen saturation, snoring, electrocardiogram findings, and body position. A sleep technician monitored the behavior and sleep position changes of the patients during sleep and manually scored all PSG data, including airflow and respiratory effort, based on the American Academy of Sleep Medicine Manual (AASM) for the scoring of sleep and associated events [8]. Respiratory events, including apnea and hypopnea, were scored according to the 'Alternative' rule. Apnea was defined as the cessation of respiratory airflow for a minimum of two breaths within 10 s. Obstructive apnea was defined as the cessation of airflow with continued respiratory effort, defined as chest and abdominal movement, for the same duration. Hypopnea was defined as a decrease in respiratory airflow of ≥ 50% with ≥ 3% oxygen desaturation or arousal.

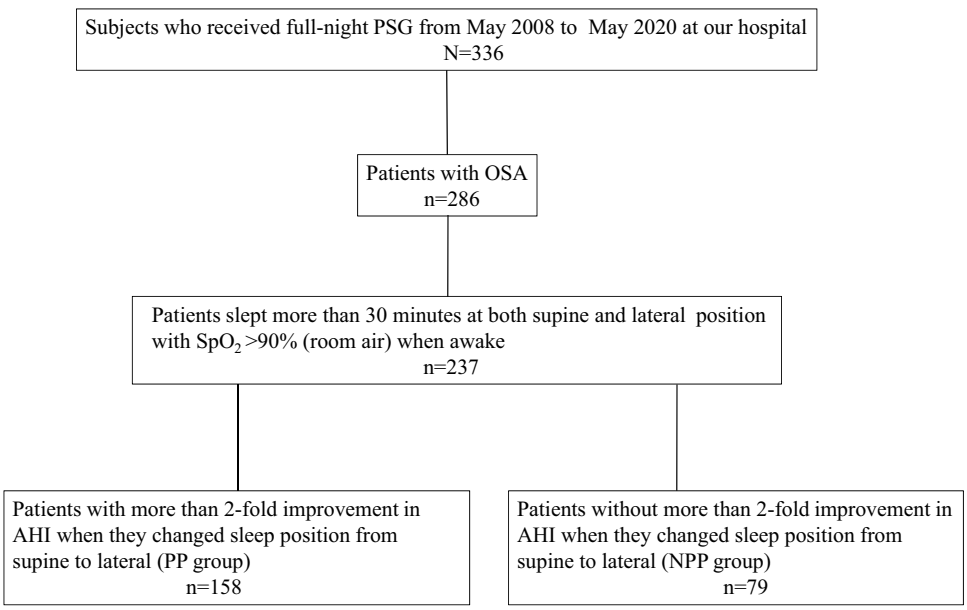

Fig. 1 The process of choosing patients who were enrolled in our study. *PSG* polysomnography; *OSA* obstructive sleep apnea; *SpO_2* oxygen saturation; *PP* positional patients; *NPP* non-positional patients

Data analysis

Statistical analyses were performed using the SPSS Statistics, version 26 (IBM, NY, USA). Measurement data are expressed as mean ± standard deviation values. Categorical variables were compared using the χ^2 test. The comparison of variables between the two groups was first assessed using the Kolmogorov–Smirnov test to confirm whether they were normally distributed. Subsequently, we confirmed that they had equal or unequal variances using the Levene's test. If they were normal and equally distributed, we used the Student's *t*-test. However, but if they were normal with an unequal distribution, we used the Welch's *t*-test. If they were not normally distributed, we used the Mann–Whitney *U* test. A logistic regression analysis for the risk factors for severe AHI levels in the PP group was performed after a univariate analysis by selecting ''AHI ≧ 30 events/h'' as the dependent variable and ''age,'' ''sex,'' ''BMI,'' and ''the percentage of supine position during sleep'' as the independent variables. A sub-analysis adjusted confounding factors by a propensity score matching method selected ''age,'' ''sex,'' ''BMI'' and ''AHI level'' as confounding factors. Statistical significance was set at $p < 0.05$. In addition, a correlation diagram was constructed using the Spearman's correlation coefficient.

Results

In all participants, a negative correlation was observed between age and BMI (Fig. 2). The ratio of PP to OSA patients was 66.7% (158/237). The PP group had an older age, a lower BMI, and a lower AHI level associated with milder nocturnal hypoxemia than the NPP group (Table 1). A logistic regression analysis for severe AHI level in the PP group indicated that the independent risk factors were BMI and the percentage of supine position during sleep (Table 2). Moreover, correlation diagrams between these two independent factors and AHI levels revealed weak positive correlations (Fig. 3). The results of the sub-analysis adjusted for confounding factors are shown in Table 3, while the AHI levels for supine and lateral sleep positions in the two groups are shown in Fig. 4. There were significant differences in nocturnal mean SpO_2, total sleep time with $SpO_2 < 90\%$ (CT90), and lowest SpO_2 between the two groups under the condition that there was no significant difference in AHI level.

Discussion

Our analysis showed that the PP group had a lower BMI and a lower AHI level associated with milder nocturnal hypoxemia than the NPP group, which was consistent with a previous report [7]. However, older ages in PP have not been reported [7, 9, 10]. In our study, the older age in the PP group may be related to the negative correlation between age and BMI (Fig. 2). Therefore, the lower BMI in the PP group may account for their older age. The reason for this negative correlation can be explained by large-scale research on Asians [11]. Lee et al. examined the physical characteristics of OSA patients by age and concluded that middle-aged patients with OSA were more likely to be obese than older OSA patients.

In a sub-analysis with no significant difference in AHI level between the two groups, there was a significant difference in nocturnal hypoxemia between them. This implied

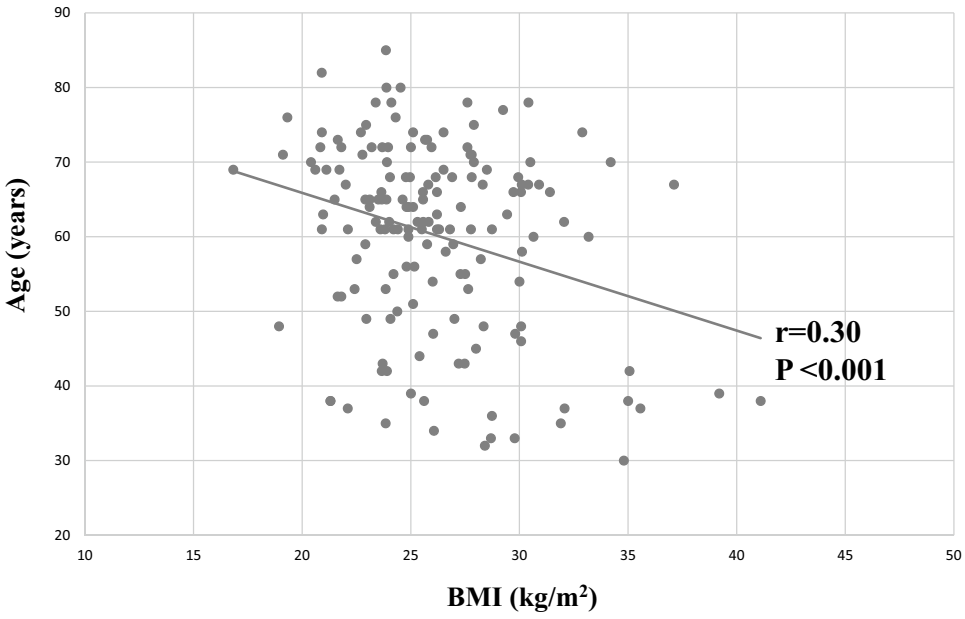

Fig. 2 The correlation diagram between age and BMI. *BMI* body mass index

Table 1 Patient's clinical background and results of PSG between with PP group and NPP group

Variables	PP	NPP	*P* value	Power
n (M/F)	158 (124/34)	79 (61/18)	0.84	Nan
Age (years)	60.3 ± 12.5	55.9 ± 14.9	0.026	0.66
BMI (kg/m^2)	26.1 ± 3.9	30.0 ± 5.1	< 0.001	1.00
SpO_2 at room air (%)	95.3 ± 0.7	94.9 ± 0.5	0.41	1.00
AHI (events/h)	25.6 ± 15.9	50.8 ± 27.1	< 0.001	1.00
AHI at supine position (events/h)	38.2 ± 21.3	50.3 ± 28.4	0.35	0.94
AHI at left lateral position (events/h)	10.3 ± 10.9	45.0 ± 26.4	< 0.001	1.00
AHI at right lateral position (events/h)	10.2 ± 11.9	43.1 ± 27.0	< 0.001	1.00
TST (min)	420.9 ± 82.9	418.4 ± 93.1	0.95	0.25
SE (%)	76.0 ± 13.5	74.5 ± 14.4	0.31	0.49
REM sleep time (%)	14.2 ± 6.0	12.0 ± 6.0	0.019	0.71
Non-REM sleep time				
Stage N1 (%)	26.7 ± 15.7	33.8 ± 21.0	0.0082	0.81
Stage N2 (%)	53.6 ± 13.7	50.8 ± 19.4	0.21	0.26
Stage N3 (%)	5.6 ± 5.9	3.4 ± 4.8	0.0029	0.83
Percentage of each position during sleep				
Supine position (%)	49.7 ± 22.0	52.4 ± 25.8	0.39	0.045
Left lateral position (%)	23.8 ± 18.6	22.0 ± 20.7	0.57	0.11
Right lateral position (%)	25.7 ± 20.8	23.5 ± 20.5	0.33	0.027
Mean SpO_2 (%)	93.8 ± 2.1	91.7 ± 3.2	< 0.001	1.00
Lowest SpO_2 (%)	78.0 ± 10.0	66.9 ± 14.4	< 0.001	1.00
3% ODI (events/h)	22.0 ± 15.5	45.6 ± 26.6	< 0.001	1.00
CT90 (%)	7.9 ± 12.3	24.8 ± 21.0	< 0.001	1.00
Arousal index (events/h)	28.6 ± 28.6	43.9.1 ± 22.6	< 0.001	0.98
Snoring index (events/h)	63.8 ± 90.4	68.1 ± 59.2	0.87	0.037

Date are expressed as mean ± standard deviation (SD)

PP positional patients; *NPP* non-positional patients; *M* male; *F* female; *Nan* not a number; *BMI* body mass index; *SpO_2* oxygen saturation; *AHI* apnea–hypopnea index; *TST* total sleep time; *SE* sleep efficiency calculated by TST/time in bed (%); *REM sleep time* rapid eye movement sleep time; *3% ODI* 3% of oxygen desaturation index; *CT90* total sleep time with SpO_2 under 90%

Table 2 A logistic regression analysis for severe level of OSA (AHI ≧ 30 events/h)

Variables	Univariate analysis	Logistic regression analysis		
	P value	*P* value	OR	95% CI
Age (years)	0.35			
Sex	0.31			
BMI (kg/m^2)	0.0020	0.0010	1.19	1.08–1.31
The percentage of supine position during sleep (%)	0.0031	0.0070	1.02	1.006–1.04

OR odds ratio; *95% CI* 95% confidence interval; *BMI* body mass index

that PP was less likely to worsen nocturnal oxygenation than did NPP. We thought this was a result of the difference in the appearance pattern of SDB according to sleep position. As shown in Fig. 4, the PP group had a marked difference in AHI level between the supine and lateral sleep positions. Contrastingly, the NPP group exhibited a small difference. Alternatively, the PP group had a severe level of SDB appearance in the supine sleep position, with a remarkable decrease in this severity in the lateral position, while the NPP group had the same degree of SDB appearance persistently in both sleep positions. Although both groups appeared to have the same severity of OSA based on total AHI level, there might be a difference in nocturnal hypoxemia due to each group's SDB appearance pattern for sleep position. In general, OSA severity was represented by the total AHI level. However, several reports concluded that nocturnal hypoxemia could contribute to the symptoms and prognosis of OSA. In particular, excessive daytime

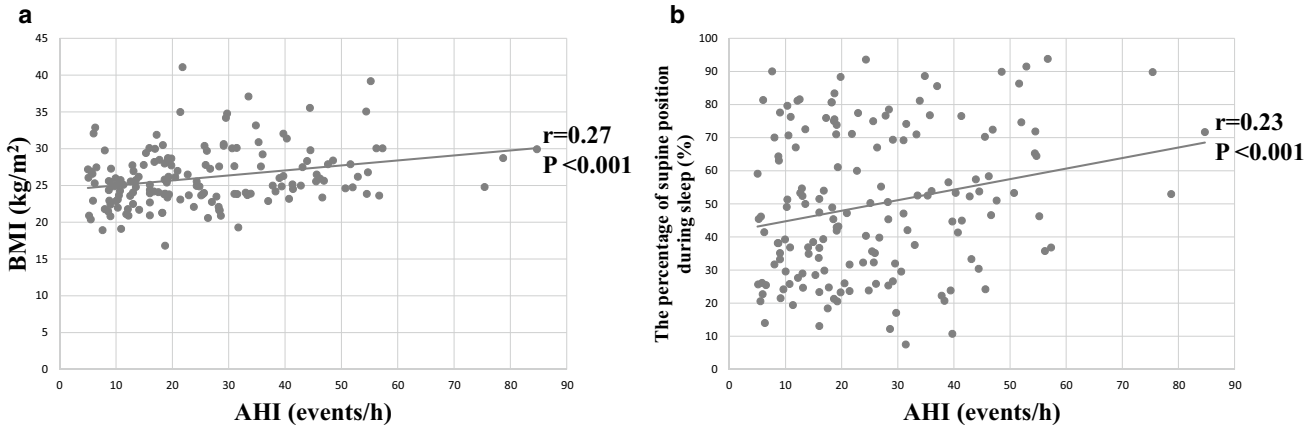

Fig. 3 The correlation diagram between AHI and BMI or the percentage of supine position during sleep for AHI level. **a** The correlation diagram between the AHI level and BMI. **b** The correlation diagram between the AHI level and the percentage of supine position during sleep. *BMI* body mass index; *AHI* apnea–hypopnea index

Table 3 Patient's clinical background and results of PSG between PP and NPP group after adjusting for confounding factors by a propensity score matching method

Variables	PP	NPP	*P* value	Power
n (M/F)	53 (42/11)	53 (42/11)	1.00	Nan
Age (years)	59.8 ± 12.9	57.9 ± 14.4	0.48	0.12
BMI (kg/m^2)	27.9 ± 4.6	28.2 ± 4.1	0.78	0.043
SpO_2 at room air (%)	95.2 ± 0.77	95.5 ± 0.22	0.91	0.73
AHI (events/h)	34.1 ± 18.2	38.4 ± 20.1	0.25	0.21
AHI at supine position (events/h)	49.5 ± 23.2	40.4 ± 24.9	0.053	0.49
AHI at left lateral position (events/h)	14.8 ± 11.2	30.8 ± 18.8	< 0.001	1.00
AHI at right lateral position (events/h)	15.1 ± 15.8	30.9 ± 15.8	< 0.001	1.00
TST (min)	419.3 ± 77.1	411.4 ± 89.1	0.63	0.071
SE (%)	76.7 ± 12.3	72.8 ± 15.0	0.14	0.32
REM sleep time (%)	13.6 ± 6.6	12.4 ± 6.1	0.34	0.16
Non-REM sleep time (%)				
Stage N1 (%)	28.1 ± 17.5	33.9 ± 19.3	0.10	0.38
Stage N2 (%)	51.3 ± 14.1	50.1 ± 17.0	0.68	0.060
Stage N3 (%)	6.8 ± 6.1	3.5 ± 4.6	0.0037	0.86
Percentage of each position during sleep				
Supine position (%)	48.8 ± 21.0	52.9 ± 25.4	0.37	0.15
Left lateral position (%)	25.5 ± 21.0	21.7 ± 21.7	0.36	0.15
Right lateral position (%)	25.0 ± 20.1	23.1 ± 19.6	0.64	0.065
Mean SpO_2 (%)	93.5 ± 2.0	92.4 ± 2.9	0.028	0.60
Lowest SpO_2 (%)	76.9 ± 11.1	70.4 ± 12.3	0.0055	0.79
3% ODI (events/hour)	29.0 ± 18.6	35.1 ± 20.8	0.17	0.33
CT90 (%)	9.9 ± 12.3	19.4 ± 19.7	0.0038	0.81
Arousal index (events/h)	32.4 ± 15.8	36.1 ± 19.1	0.31	0.19
Snoring index (events/h)	66.8 ± 66.9	63.0 ± 64.8	0.83	0.049

Date are expressed as mean ± standard deviation (SD)

PP positional patients; *NPP* non-positional patients; *M* male; *F* female; *Nan* not a number; *BMI* body mass index; *SpO_2* oxygen saturation; *AHI* apnea–hypopnea index; *TST* total sleep time; *SE* sleep efficiency calculated by TST/time in bed (%); *REM sleep time* rapid eye movement sleep time; *3% ODI* 3% of oxygen desaturation index; *CT90* total sleep time with SpO_2 under 90%

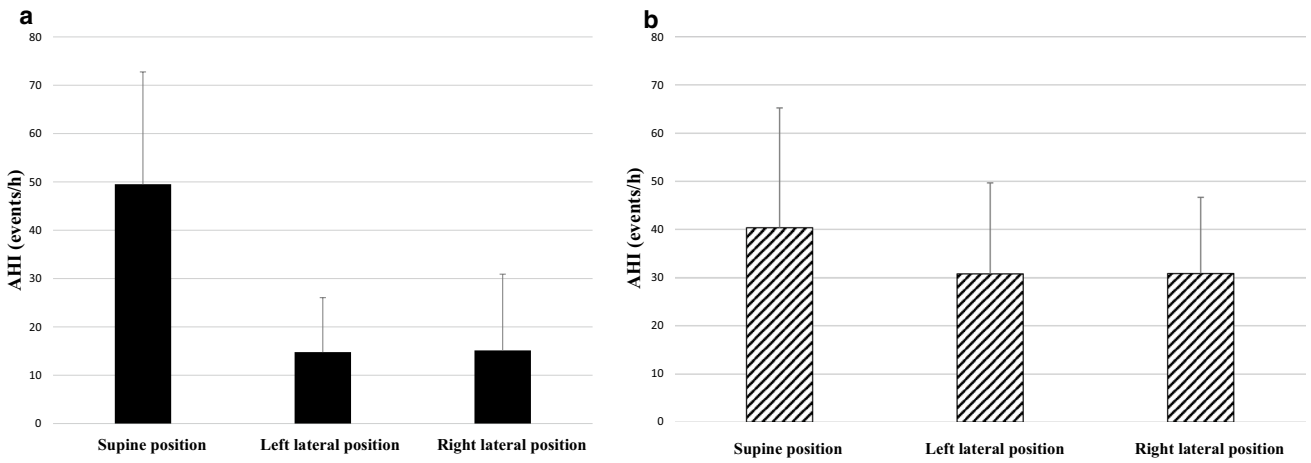

Fig. 4 The AHI level at supine and lateral sleep positions in a confounding factor adjusted sub-analysis. **a** The AHI level at supine and lateral sleep positions in the PP group. **b** The AHI level at supine and lateral sleep positions in the NPP group. *AHI* Apnea–hypopnea index, *PP* positional patients; *NPP* non-positional patients

sleepiness (EDS), which is a typical symptom of OSA, has been verified as a cause of OSA [12, 13]. These reports showed that OSA patients with EDS had a worse nocturnal hypoxemia than those without EDS. Furthermore, these reports concluded that nocturnal hypoxemia, rather than AHI level, might play a primary role in daytime sleepiness. The relationship between nocturnal hypoxemia and sleepiness is unknown. However, one of the leading hypotheses is that intermittent hypoxemia during sleep leads to neural cell injury and apoptosis through the convergence of inflammatory and oxidative stress pathways. Such deleterious events specifically target wake-promoting regions within the central nervous system, thereby leading to the emergence of sleepiness [14–17]. The symptoms of OSA and its prognosis can be related to nocturnal hypoxemia. Gami et al. performed a large-scale longitudinal study targeting 10,701 adults who underwent full-night PSG. During a follow-up period of 5.3 years, 142 patients were either resuscitated or experienced a fatal sudden cardiac death. Their risk factors were verified using multivariate analysis. The analysis indicated that the lowest SpO_2 level was a more significant predictor than AHI level [18].

A reason for fatal OSA complications such as cardiovascular disease is endothelial dysfunction, which is caused by sympathetic overactivity, oxidative stress, and SDB-associated inflammation [19, 20]. Sawatari et al. investigated the degree of vascular endothelial dysfunction using flow-mediated vasodilation response in patients with OSA who underwent full-night PSG examination [21]. They found that cumulative hypoxemia during sleep, rather than AHI level, was a predictor of endothelial damage. Considering these factors, the NPP probably has severe nocturnal hypoxemia in addition to severe AHI levels; therefore, their prognosis can be worse than that of PP.

Our study has several limitations. First, we could not compare the prognosis between the PP and NPP groups because our study was conducted at a single institute, and the sample size was small. Second, we included patients who slept for 30 min each in the supine and lateral positions based on the methodology of previous reports [7]; however, we did not know whether the time was adequate. Since the AHI level could vary according to sleep stage (rapid eye movement [REM] and non-REM sleep), the time of cycle was dependent on the person. Hence, the result may change depending on the inclusion criteria.

In conclusion, the PP group had an older age, a lower BMI, and a lower AHI level associated with milder nocturnal hypoxemia compared with those of NPP. Furthermore, their severity depended on BMI and the percentage of supine position during sleep. Moreover, nocturnal hypoxemia might be less likely to worsen because of the appearance pattern of SDB according to sleep position.

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Declarations

Conflict of interest For this study, we did not receive financial support from any organization.

Research involving human and/or animals This study was conducted in accordance with the ethical principles described in the Declaration of Helsinki, the Japanese Ethical Guideline for Epidemiologic Research and all other applicable laws and regulations.

Ethics approval The study was approved by the research ethics committee of Shinshu University School of Medicine (Permission number: 5008). The study protocols were performed in accordance with the principles outlined in the Declaration of Helsinki of the World Medical Association.

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