Original Article

Effect of Lateral Body Position on Heart Rate Variability in Patients with Sleep Apnea Syndrome

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Sleep apnea syndrome (SAS) can exacerbate cardiovascular disease by augmenting activity of the sympathetic nervous system. One method of treating SAS is via modulation of body posture. Therefore, the goal of the present study was to investigate whether assuming the lateral position during sleep can influence autonomic nervous system activity, as assessed by measurement of heart rate variability (HRV). Six patients with coronary artery disease (CAD) complicated by SAS underwent serial measurements of HRV and arterial blood oxygen saturation (SpO_2) during sleep. Online analyses for HRV was performed using five consecutive RR intervals from electrocardiography using the modified Maximum Entropy Method. Low frequency spectra (LF, 0.04–0.15 Hz), high frequency spectra (HF, 0.15–0.40 Hz) and the ratio of low and high frequency spectra (LF/HF ratio) were continuously calculated. HRV and SpO_2 measurements were performed after 30 min of sleep in different sleeping positions (supine vs. lateral) with or without supplementary oxygen administration by nasal cannula. The LF and LF/HF ratio were significantly smaller in the lateral position with and without oxygen when compared with the supine position with or without oxygen (LF: Supine to Lateral position, from $673 \pm 643\,ms^2/Hz$ to $201 \pm 221\,ms^2/Hz$, $P < 0.05$; Supine to Lateral position with supplementary oxygen, from $617 \pm 511\,ms^2/Hz$ to $288 \pm 389\,ms^2/Hz$, $P < 0.05$; LF/HF ratio: Supine to Lateral position, from 9.4 ± 643 to 2.9 ± 1.9, $P < 0.05$; Supine to Lateral position with supplementary oxygen, from 6.1 ± 3.5 to 2.3 ± 1.5, $P < 0.05$). Further, arterial blood oxygen saturation was higher in the lateral position than in the supine position and was higher with supplementary oxygen than without supplementary oxygen (Supine, $86.7 \pm 4.3\%$; Lateral, $94.5 \pm 0.8\%$; Supine+O_2, $93.2 \pm 4.5\%$; Lateral+O_2, $98.2 \pm 1.5\%$). In conclusion, the lateral position during sleep attenuated sympathetic nervous system activity and improved oxygenation in patients with concomitant CAD and SAS.
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Key words: Autonomic nerve activity, Body posture, Hypoxia, Apnea

Introduction

Sleep apnea syndrome (SAS) can cause or exacerbate systemic hypertension, pulmonary hypertension, arrhythmias, and coronary artery disease (CAD). This is supported by reports that 16% of

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patients with SAS experience cardiovascular morbidity, while 30–39% of patients with CAD have concomitant SAS.[1–5] Further, several groups have demonstrated that alterations of heart rate variability (HRV) are frequently observed in patients with SAS. Other investigators have reported that HRV may participate in the pathophysiology of SAS and that HRV can be used as a diagnostic tool and as a screening parameter for the efficacy of various treatments for SAS.[6–9]

The severity of sleep apnea can vary according to body posture.[10,11] For example, the lateral body position promotes patency of the upper respiratory tract and can thereby reduce apnea frequency in patients with SAS[12,13] and potentially reduce cardiovascular morbidity and mortality via normalization of sympathetic nervous system activity.

Therefore, the goal of the present study was to investigate whether assuming the lateral position during sleep can influence autonomic nervous system activity, as assessed by measurement of HRV.

Methods

1. Study population

Thirty consecutive patients with CAD were referred to the Self Defense Forces Central Hospital and were subsequently admitted for elective percutaneous coronary intervention (PCI). Nighttime arterial blood oxygen saturation (SpO_2) was monitored by pulse oximetry with a finger transducer (Ohmega Biox 3700, Louisville, Colorado, USA). Patients with at least one episode of a fall >3% in SpO_2 or absolute SpO_2 values <94% were enrolled in the present study (n = 6). As it was described later, SAS was subsequently diagnosed in all these patients. All study participants were men (age range, 43–74 years; mean age, 60.7 ± 11.4 years), and average body mass index was $26.5 \pm 3.9\,kg/m^2$. Pertinent history included tobacco use (n = 6), hypertension (n = 4), hyperlipidemia (n = 3), and family history of CAD (n = 2). None of the patients had a diagnosis of diabetes mellitus and cerebrovascular diseases. Cardiac catheterization revealed that average left ventricular ejection fraction was $55 \pm 3\%$ and none of the patients had impaired left ventricular function. Medication profiles included nitrates (n = 3), calcium channel blockers (n = 2), statins (n = 3), angiotensin II receptor blockers (n = 4), beta-blockers (n = 2), and aspirin (n = 6). All patients were aware of the investigative nature of the study and gave informed consent. All protocols were approved by the local institutional ethics committee.

2. Study protocol

Patients were hospitalized in quiet, calm, and comfortable rooms equipped with visual video-camera monitors. Patients went to bed at approximately 21:00. Two-channel electrocardiogram (ECG) was conducted using a bedside vital sign monitoring system (Hewlett Packard model 66, Andover, MA, USA), and SpO_2 was monitored using a pulse oximetry finger transducer. ECG and pulse oximetry signals were transferred to a personal computer for further analysis.

HRV indices were measured with commercialized software (MemCalc/Tarawa, Suwa Trust Inc., Tokyo, Japan), based on the RR intervals of normal sinus beats obtained from the ECG throughout the entire study period that were stored on the personal computer. For frequency domain analysis, online analysis was performed for five consecutive RR intervals using the modified Maximum Entropy Method. Low frequency spectra (LF, 0.04–0.15 Hz) and high frequency spectra (HF, 0.15–0.40 Hz) were continuously calculated. The ratio of low frequency spectra and high frequency spectra was also measured as the LF/HF ratio.

Thereafter, SpO_2, heart rate, and HRV indices were averaged over 10-min periods at the following measuring points: approximately 30 min after falling asleep with the patient in the supine position (Supine), approximately 30 min after falling asleep with the patient in the lateral position (Lateral), approximately 30 min after falling asleep with the patient in the supine position with supplementary oxygen (Supine+O_2) and approximately 30 min after falling asleep with the patient in the lateral position with supplementary oxygen (Lateral+O_2). For the supplementary oxygen conditions, 100% oxygen was administered via nasal cannula at a rate of 2 L/min. Sleeping condition was monitored by one of the investigators using a video-camera equipment to determine the sleeping status of the patients.

3. Statistics

Data are expressed as mean ± SD if not otherwise stated. Changes in each parameter were compared by repeated measures of analysis of variance (ANOVA) with Scheffe's correction if not otherwise stated. Correlation analysis was performed using Person product-moment correlation. All statistical analyses were performed using SPSS version 11.0 (SPSS Japan Inc., Tokyo, Japan). $P < 0.05$ was considered to represent statistical significance.

Results

Awake SpO_2 was within normal limits on room air in all patients ($SpO_2 = 96.3 \pm 1.0\%$). However, SpO_2 significantly decreased from $96.3 \pm 1.0\%$ to $86.7 \pm 4.3\%$ during sleep in the supine position. In contrast, heart rate was relatively stable during the entire study protocol (Supine, 62 ± 5 beats/min; Lateral, 64 ± 4 beats/min; Supine+O_2, 61 ± 5 beats/min; Lateral+O_2, 62 ± 6 beats/min; NS). Further, changes in body posture did not influence heart rate in this study.

By watching the video-camera monitor, either apnea or breathing difficulty such as snoring or hypopnea was observed in all patients in this study (apnea in 3 patients and snoring in 3 patients). SpO_2 had been monitored in each patient for the entire sleep period at night when this study was conducted by using a pulse oximetry finger transducer while watching the breathing pattern through video-camera monitoring. Hourly averaged number of episode of a fall $>3\%$ in SpO_2 from the baseline value of SpO_2 (awake hourly averaged value) was defined as oxygen desaturation index (ODI 3%) according to the American Academy of Sleep Medicine Task Force.[14] ODI 3% in each patient is listed in **Table 1**. All episodes of a fall $>3\%$ in SpO_2 lasted for >10 seconds and apnea (≥ 5 per hour of sleep) was observed by video-camera monitoring in each patient. In addition, all patients complained of a lack of a sense of a good night's sleep, so all patients in this study were considered to meet the criteria of SAS based on the American Academy of Sleep Medicine Task Force[14] even though polysomnography was not performed.

There were significant changes in HRV indices and SpO_2 during the study protocol. Being compared from supine to lateral position, HF decreased from $172 \pm 166\,ms^2/Hz$ to $72 \pm 59\,ms^2/Hz$. Further, in the same comparison under supplementary oxygen, HF decreased from $170 \pm 163\,ms^2/Hz$ to $127 \pm 120\,ms^2/Hz$ (**Figure 1**). A similar trend was noted with LF and the LF/HF ratio.

The LF and LF/HF ratio was significantly lower in the lateral position than in the supine position (**Figures 2 and 3**) (LF: Supine to Lateral position, from $673 \pm 643\,ms^2/Hz$ to $201 \pm 221\,ms^2/Hz$, $P < 0.05$; Supine to Lateral position with supplementary oxygen, from $617 \pm 511\,ms^2/Hz$ to $288 \pm 389\,ms^2/Hz$, $P < 0.05$; LF/HF ratio; Supine to Lateral position, from 9.4 ± 643 to 2.9 ± 1.9, $P < 0.05$; Supine to Lateral position with supplementary oxygen, from 6.1 ± 3.5 to 2.3 ± 1.5, $P < 0.05$). Further, arterial blood oxygen saturation was higher in the lateral position than in the supine position and was higher with supplementary oxygen than without supplementary oxygen (**Figure 4**) (Supine, $86.7 \pm 4.3\%$; Lateral, $94.5 \pm 0.8\%$; Supine+O_2,

Table 1 Breathing pattern during sleep and oxygen desaturation index in each patient.

Case Number	Age	Type of Breathing Disorder	Oxygen Desaturation Index (ODI 3%)
Case 1	43	Apnea	11
Case 2	63	Snoring	5
Case 3	74	Snoring	8
Case 4	69	Snoring	11
Case 5	63	Apnea	10
Case 6	52	Apnea	5

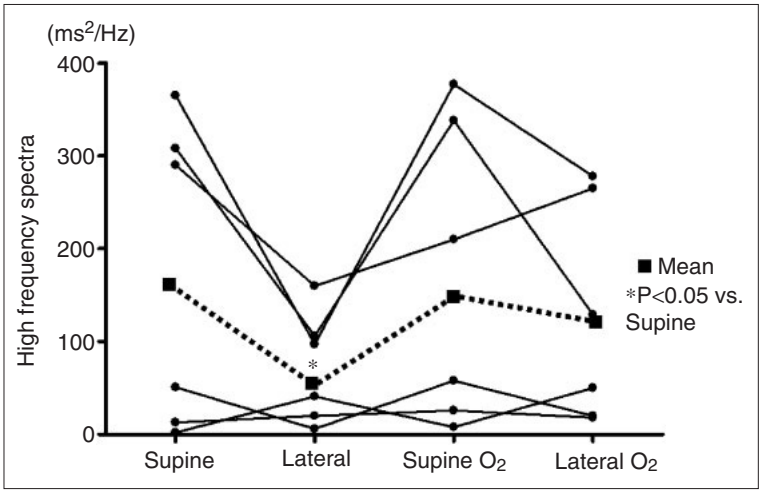

Figure 1 Effect of the lateral position and supplementary oxygen on the high frequency spectra.
High frequency spectra were obtained approximately 30 min after falling asleep in the supine (Supine) or lateral position (Lateral). Similar experiments were conducted with the addition of supplementary oxygen as delivered by nasal cannula (Supine O_2, Lateral O_2). Closed square and dotted line represent the mean values and their changes.

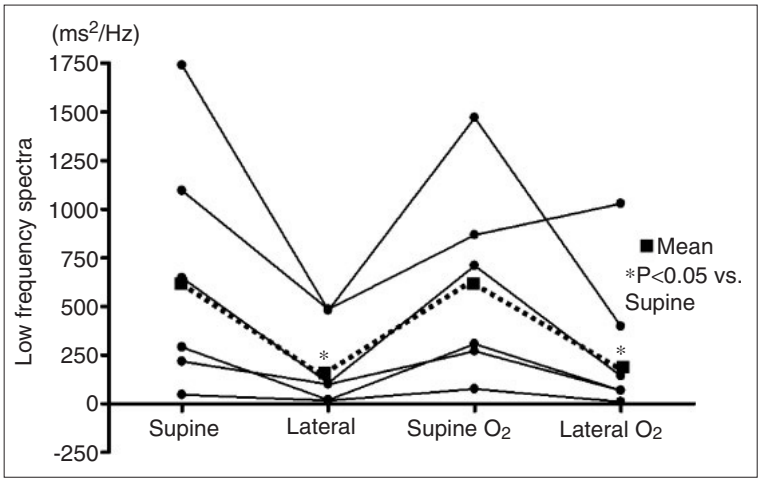

Figure 2 Effect of the lateral position and supplementary oxygen on low frequency spectra.
Format and abbreviations are similar to those described in Figure 1.

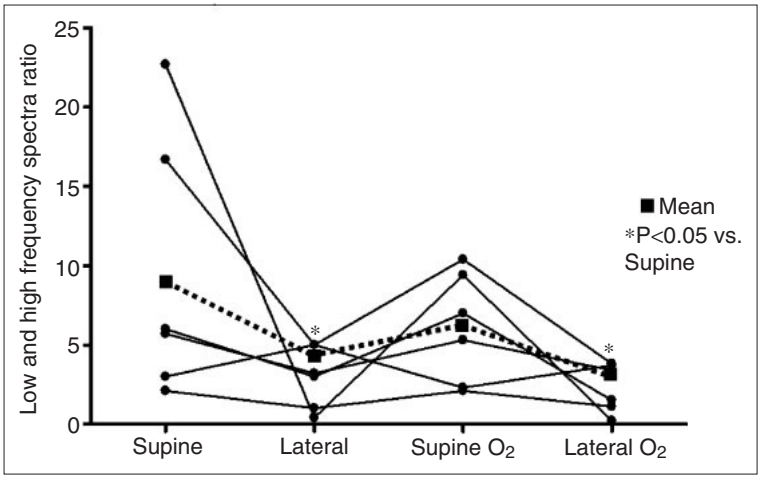

Figure 3 Effect of the lateral position and supplementary oxygen on low and high frequency spectra ratio.
Format and abbreviations are similar to those described in Figure 1.

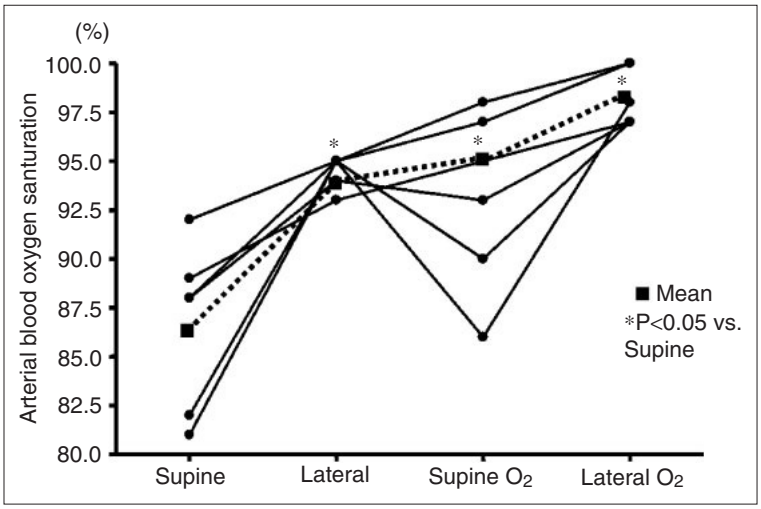

Figure 4 Effect of the lateral position and supplementary oxygen on arterial blood oxygen saturation.
Format and abbreviations are similar to those described in Figure 1.

$93.2 \pm 4.5\%$; Lateral+O_2, $98.2 \pm 1.5\%$). In summary, if the effects of postural change (from supine to lateral) and supplementary oxygen administration on HRV indices were separately compared, postural change itself significantly decreased each mean value of HRV indices, whereas supplementary oxygen administration did not influence any HRV indices.

Changes in each HRV index tended to correlate with changes in SpO_2 (correlation coefficients, 0.45–0.56), but this relationship was weak and did not reach the level of statistical significance.

Discussion

The present study demonstrated that the lateral position resulted in attenuation of sympathetic nervous system activity (as documented by HRV measurements[15,16]) and improved oxygenation in patients with CAD and SAS, which is consistent with results from previous studies.[10,11,15–20] This effect of the lateral position of oxygenation may result from the ability of the lateral position to promote upper respiratory tract patency by relieving the gravitational forces on the tongue and soft palate. Further, the lateral position likely attenuated SAS-induced increases in sympathetic nervous system activity, as demonstrated by the decreases in LF and the LF/HF ratio, which reflect the afferent sympathetic activity to the heart.[15–17,21] Indeed, other studies have reported that non-supine sleeping positions can decrease blood pressure in hypertensive patients.[22]

The mechanisms by which the lateral position affects the HRV and SpO_2 may be distinct, as there was no significant correlation between changes in HRV and changes in SpO_2 in the present study. The possible mechanism by which the lateral position leads to improved SpO_2 was already discussed above: relieving the gravitational forces on the tongue and soft palate. Previous studies[23,24] have reported that HRV can be modulated by vagal feedback between stretch receptors, central medullary coupling between respiratory and cardiovagal neurons, and arterial baroreflex-induced fluctuations. Further, the latter mechanism may be the most prominent in SAS-induced changes in sympathetic nervous system activity.[23,24] However, various other factors can separately affect autonomic nervous system activity and SpO_2, including changes in baroreceptor sensitivity, chemoreceptor sensitivity, hypoxemia, upper airway response, ventilatory changes, and arousal. Since only chemoreceptor sensitivity and hypoxemia can be invoked to explain a relationship between HRV and SpO_2,[23,24] it is likely that the lateral position modulates each of these parameters via different mechanisms.

Study limitations: The present study did not investigate the effect of sleep stage on experimental parameters, and previous studies have demonstrated that autonomic nerve activity and SpO_2 are both influenced by sleep stage.[12,15] However, all the measurements on HRV and SpO_2 were performed at approximately 30 min after the patient fall asleep. Thus, all participants were probably in the same stage of sleep. In addition, polysomnography study was not performed in order to diagnose SAS in the present study as described earlier. However, mean decrease of SpO_2 during sleep was about 10% (from $96.3 \pm 1.0\%$ to $86.7 \pm 4.3\%$) as well as ODI 3% and the frequency of observed apnea during sleep strongly supporting the diagnosis of SAS in this study population. Measuring the HRV indices for patients with SAS has some limitations because periodic hyper- and hypoventilation is a typical feature of SAS. And this periodic ventilation can influence the measures of HRV indices, and especially the periodic hyperventilation increases the value of HF. Since the lateral position significantly improved SpO_2, the frequency of these periodic ventilations reduced in the lateral position. The decrease of HF value was partly and probably due to the decrease of periodic ventilation rather than the decrease of vagal nerve activity whereas the decrease of LF and LF/HF values by the lateral position indicated the significant attenuation of sympathetic nerve activity. In addition, even if respiratory frequency could influence HF value, the previous reports confirmed the validity of the measurement of HRV indices in SAS.[6–9] Another limitation of the present study was the small number of participants; further study in larger populations would be of benefit to confirm the present observations.

In conclusion, the lateral position during sleep attenuated sympathetic nervous system activity and improved oxygenation in patients with concomitant CAD and SAS. This strategy may be a cheap and effective method of improving cardiovascular outcomes in patients with SAS.

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