Effects of Body Position on Snoring in Apneic and Nonapneic Snorers

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Study Objectives: The positional dependency of obstructive sleep apnea (OSA) is well known, but objective evidence for the positional effect on snoring is lacking. The aim of this study is to elucidate the effect of body position on snoring, and that of sleep stage as well.

Design: Retrospective analysis of the effects of body position and sleep stage on snoring in nonapneic snorers (snorer group) and OSA patients (apneic group).

Setting: A sleep laboratory in a national hospital in Japan.

Patients: Seventy-two patients who complained of habitual snoring and underwent overnight polysomnography.

Interventions: N/A

Measurements and Results: In the lateral position, most subjects in the snorer group showed decreased snoring both in time (p=0.0004) and intensity (p=0.0003), but subjects in the apneic group showed variable changes. In the apneic group, the positional dependency of snoring (the ratio of lateral value to supine value) was correlated with supine apnea-hypopnea index (AHI), that is, OSA patients with higher supine AHI tended to show increased snoring in the lateral position. As to the effect of sleep stage, snoring was increased in deeper non-rapid eye movement sleep and decreased in rapid eye movement sleep in a given position.

Conclusions: This study demonstrated that the positional dependency is different between nonapneic snorers and OSA patients. Most of the nonapneic snorers snore less in the lateral position than in the supine position in contrast to OSA patients who often fail to decrease snoring even in the lateral position.

Key Words: Sleep apnea; snoring; posture; polysomnography; sound; sleep stage

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INTRODUCTION

IT IS WELL DOCUMENTED THAT PATIENTS WITH OBSTRUCTIVE SLEEP APNEA (OSA) OFTEN HAVE MORE APNEA EVENTS IN THE SUPINE POSITION THAN IN THE LATERAL POSITION,[1-5] and positional treatment is effective in these patients.[6] The positional OSA patients are reported to be thinner and have less severe apnea than nonpositional patients.[3] An anatomic study of upper airways in OSA patients revealed that positional patients have a larger minimum cross-sectional area and a larger minimum lateral distance than nonpositional patients, and they show an increase in anteroposterior distance when turning to the lateral position.[7] Therefore positional OSA is considered to be a less severe subgroup in OSA. Patients with OSA almost always have habitual snoring, and habitual snoring without OSA is thought to be a precursor to OSA.[8] Therefore it is anticipated that position affects snoring as well. Anecdotally it is known that many patients snore less in the lateral position than in the supine position.[9] However, to date there has been no detailed study focusing on the positional dependency of snoring. Thus the main purpose of this study was to describe the effect of position on snoring in nonapneic snorers and OSA patients. We also described the effect of sleep stage, which is also known to affect apnea events, on snoring in those subjects.

METHODS

Subjects

The subjects were 81 sequential patients who complained of habitual snoring and underwent overnight polysomnography for the diagnosis of sleep-disordered breathing. Nine patients were excluded because they had little or no sleep (less than 10 minutes) while in the lateral position. Data analyses were performed on the remained 72 patients. Based on the apnea-hypopnea index (AHI), we classified the subjects into nonapneic snorer group (snorer: AHI<15) and OSA group (apneic: AHI≥15).[10] Patients with predominantly central type apnea events were not included among the subjects.

Polysomnography

Polysomnography was recorded using a polygraph system (EEG7414, Nihon Kohden, Japan). Electroencephalogram (C3-A2), bilateral electrooculogram, submental electromyogram (EMG), electrocardiogram, and bilateral anterior tibial EMG were recorded. Oronasal airflow was monitored with a thermistor. Thoracic and abdominal respiratory movements were monitored by inductive plethysmography (Respitrace, Ambulatory Monitoring Inc., USA), which was calibrated by isovolume maneuver before the test. Oxyhemoglobin saturation was monitored using pulse oximetry (Pulsox3i, Minolta, Japan) with a finger probe. Body position was measured by a position sensor (SPI, Pro-Tech, USA) attached to the anterior chest wall on the median line. The sensor differentiated five positions of supine, right lateral, left lateral, prone, and upright. Tracheal sound was recorded from an air-coupled microphone (ECM140, SONY, Japan) attached on the neck over the trachea. The recording system of tracheal sound was calibrated by reference sound pressure (94 dB). All signals were digitized and recorded on the hard disk of a personal computer. Sleep stages were scored manually according to the standard criteria of Rechtschaffen and Kales.[11] Apnea was defined as an episode of a complete airflow cessation lasting more than 10 seconds, and hypopnea was defined as an episode of reduced tidal volume to less than 50% of preceding value lasting more than 10 seconds.[10] An AHI was calculated as the number of apneas plus hypopneas per hour of sleep.

Analysis of Snoring Sound

Tracheal sounds were analyzed using the PC-based compressed sound spectrograph system that we had developed for the analysis of snoring.[12] Briefly, tracheal sounds were digitized at a sampling frequency of 11025

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No significant financial interest/other relationship to disclose.

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Hz, and power spectra calculated by a fast-Fourier transform for 1024 points were stored in the hard disk of the PC every 0.2 seconds. The system automatically detected snoring using the criteria in which a peak value of power spectral density over 70 dB/Hz within the frequency bandwidth of 100 to 300 Hz was defined as snoring. In the preliminary study in 792 six-second sound blocks from overnight tracheal sounds records in 22 snorers, the sensitivity and specificity for the detection of snoring sounds defined by listening were 96% and 88%, respectively. In the present study, we examined the whole overnight sound spectrogram and excluded body movement noises and voice sounds from the automatically detected segments.

We defined snoring time as the absolute time when the power spectral density exceeded the threshold and expressed it as the percentage in total time of sleep in specific stages and /or positions. For example, if snoring is detected in whole inspiratory phase of every breath and the ratio of inspiratory phase to expiratory phase is 1:2, the snoring time is calculated to be 33%. We defined snoring intensity as a geometric mean of the sound pressure (= arithmetic mean in dB) of snoring at the skin surface of the neck. The snoring intensity was calculated only when the snoring time was 1% or more for specific sleep stages and/or position.

Statistical Analysis

Between-groups comparisons were made using unpaired t-tests. Within-group comparisons between the supine and lateral positions were made using paired t-tests. To investigate the effect of body position, sleep stage, and the interaction on snoring, we used repeated measures two-way ANOVA with Bonferroni's test. Correlations between position dependence of snoring and other parameters were evaluated using Pearson's correlation coefficient. Multivariate regression analysis was also carried out to determine the independent effects of selected variables. A p value of <0.05 was considered to be significant.

Table 1—Subjects characteristics

	Snorers	Apneics
N	21	51
Age (years)	49.0±14.5	49.9±12.3
Male, N (%)	12(57.1)	45(88.2) **
Body mass index (kg/m²)	24.0±2.8	28.8±5.8 **
Polysomnography		
Total recording time (min)	472.4±18.9	479.3±12.8
TST (min)	361.2±76.7	362.9±58.5
Sleep efficiency (%)	76.3±16.0	75.7±11.8
Stage 1(%TST)	18.3±8.7	36.2±20.4 **
Stage 2(%TST)	62.8±7.6	48.8±18.9 **
SWS (%TST)	2.5±3.8	0.7±1.3 *
REM (%TST)	14.6±7.9	14.0±5.6
AHI (/hr)	7.5±3.7	54.7±27.6 **
Snoring time (%TST)	14.8±10.4	20.7±11.5 *
Snoring intensity (dB)	101.6±3.3	103.2±3.6

Data are presented as mean±SD. *:p<0.05; **:p<0.01
TST, total sleep time; SWS, slow wave sleep; REM, rapid eye movement; AHI, apnea hypopnea index; dB, decibel

Table 2—Positional changes in sleep and breathing parameters

	Supine	Lateral	Difference (p)
Snorers			
Stage 1 (%TST)	25.0±19.6	20.5±20.0	0.4866
Stage 2 (%TST)	61.1±16.8	57.8±19.4	0.5744
SWS (%TST)	1.4±1.8	2.8±5.8	0.2567
REM (%TST)	12.5±9.0	19.0±15.3	0.1221
AHI (/hr)	14.4±11.0	2.9±3.7	0.0002
Snoring time (%TST)	17.5±10.3	6.4±7.1	0.0004
Snoring intensity (dB)	102.6±3.6	98.3±4.3	0.0003
Apneics			
Stage 1 (%TST)	46.0±24.4	30.3±24.7	<0.0001
Stage 2 (%TST)	45.0±23.9	49.1±21.5	0.1814
SWS (%TST)	0.4±0.7	1.0±3.3	0.1826
REM (%TST)	8.6±6.4	19.6±12.5	<0.0001
AHI (/hr)	71.1±27.4	41.3±31.4	<0.0001
Snoring time (%TST)	16.9±10.8	15.4±10.1	0.3277
Snoring intensity (dB)	102.9±3.8	103.5±4.4	0.5065

Data are presented as mean±SD.
TST, total sleep time; SWS, slow wave sleep; REM, rapid eye movement; AHI, apnea hypopnea index; dB, decibel

RESULTS

Characteristics of the Subjects

Of the 72 subjects, 21 were snorers and the other 51 were apneics (Table 1). The mean age was not different between the two groups. The apneic group was predominantly male compared to the snorer group. The body mass index (BMI) was significantly greater in the apneic group. The apneic group tended to have lighter stage in non-rapid eye movement (NREM) sleep compared to the snorer group.

Effects of Body Position on Sleep, Breathing and Snoring

Snorers. There was no difference in sleep architecture between supine and lateral positions (Table 2). The AHI was lower in the lateral position than in the supine position. The positional dependence of AHI (defined by lateral AHI / supine AHI < 0.5) was found in 16 (76%) out of 21 subjects.

Snoring time as well as snoring intensity was lower in the lateral position than in the supine position (Figure 1, Figure 2). More than a 50% decrease in snoring time in the lateral position was observed in 15 (71%) out of 21 subjects. Conversely, more than a 50% increase in snoring time in the lateral position was observed in only 1 subject (5%).

Apneics. The subjects tended to have less stage 1 sleep and more REM sleep in the lateral than in the supine position. The AHI was lower in the lateral position than in the supine position. The positional dependence of AHI was found in 25 (49%) out of 51 subjects.

Neither snoring time nor intensity had statistically significant positional differences (Figure 1, Figure 2). More than a 50% decrease in snoring time in the lateral position was observed in 9 (18%) out of 51 subjects. Conversely, more than a 50% increase in snoring time in the lateral position was observed in 12 subjects (24%).

Effects of the Interaction of Sleep Stage and Position on Snoring

Snorers. In 7 subjects in whom all sleep stages were observed in both positions, a two-way ANOVA revealed significant effects of sleep stage and position on snoring time (Figure 3). Snoring time tended to be greater in deeper NREM sleep. It also revealed a significant effect of position on snoring intensity. There was no significant interaction between sleep stage and position. The result was the same when the analyses were performed in 15 subjects in whom stage 1, stage 2, and REM

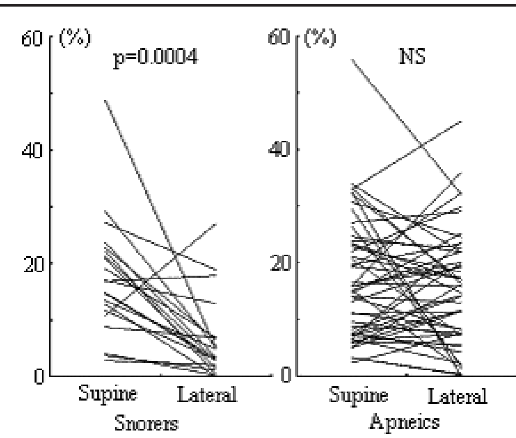

Figure 1—Change in snoring time between supine position and lateral position in snorer group and in apneic group.

sleep were observed in both positions.

Apneics. In 7 subjects in whom all sleep stages were observed in both positions, a two-way ANOVA revealed that only sleep stage had a significant effect on snoring time (Figure 4). It also revealed a significant effect of sleep stage on snoring intensity. Both snoring time and intensity tended to be greater in deeper NREM sleep. Position was shown to have no significant effect on either snoring time or intensity. There was no significant interaction between sleep stage and position. The result was also the same when the analyses were performed in 37 subjects in whom stage 1, stage 2, and REM sleep were observed in both positions.

Correlation Between Positional Dependency of Snoring and Other Parameters

The snorer and apneic groups were different in gender distribution and BMI as well as AHI. Therefore it was considered to be possible that the difference in positional change in snoring was due to the difference in these characteristics other than AHI. To elucidate this point, we analyzed the correlations between positional change in snoring and the other parameters in all the subjects (Table 3).

The positional change in snoring was correlated with AHI, especially that in supine position. The relationship was preserved after an adjustment for gender and BMI. Gender was correlated with the positional dependency, but the relationship was insignificant when adjusted for AHI. The correlation between positional dependency of snoring and BMI was insignificant.

DISCUSSION

The major findings in this study were 1) in the lateral position most subjects in the snorer group showed decreased snoring both in time and intensity, but subjects in the apneic group showed variable changes 2) subjects with higher supine AHI tended to show increased snoring both in time and intensity in the lateral position, 3) in a given position snoring was increased in deeper NREM sleep.

The Effect of Body Position on Snoring

In the present study, the positional dependency of AHI was found in 76% and 49% of the subjects in the snorer group and apneic groups, respectively, which were approximate to documented values in other studies.[3-4] As to snoring, the positional dependency was quite different between the snorer group and the apneic group. In the snorer group, the positional dependency of snoring was similar to that of apnea/hypopnea events, that is, they snored less in the lateral position. In contrast, in the apneic group, many patients didn't show decreased snoring and some patients showed increased snoring in the lateral position as compared to the supine position.

There are only a few studies related to this issue. Braver et al[13] reported that positional therapy was not effective for snoring. Their study was different from the present study in method and purpose. They compared the frequency of snoring between the nights with and without positional therapy, which allowed lateral position in the control night. Therefore their study is inconclusive as to positional change in snoring. We think the present study may support their findings. Oksenberg et al[14], in their study about positional effects on apneic events in severe OSA, revealed that the maximal intensity of snoring at apneic events was greater in the supine position than in the lateral position. Their analysis of snoring was confined to apneic events, and the change in snoring as a whole was not addressed. To the best of our knowledge, the present study is the first one focusing on the positional effect on snoring.

The positional dependency of snoring was present only in the snorer group. The difference in characteristics between the snorer group and the apneic group were gender distribution and BMI as well as severity of sleep-disordered breathing (AHI). The positional change in snoring correlated with AHI and gender and didn't correlate significantly with BMI. The correlation between gender and the positional dependency was also not significant when adjusted for AHI. Therefore we think the major determinant of positional dependency of snoring is severity of OSA.

Table 3—Correlation coefficients between positional change in snoring (the ratio of lateral value to supine value) and the other parameters

	Snoring time	Snoring intensity
Gender	0.284 *	0.345 **
Body mass index	0.154	0.238
AHI	0.355	0.435
Supine AHI	0.506 ****	0.597 ****
Lateral AHI	0.271 *	0.408 ***
AHI Lateral/Supine[a]	0.143	0.349 **

AHI, apnea hypopnea index.
*:p<0.05; **:p<0.01; ***:p<0.001; ****:p<0.0001
[a]The ratio of lateral AHI to supine AHI.

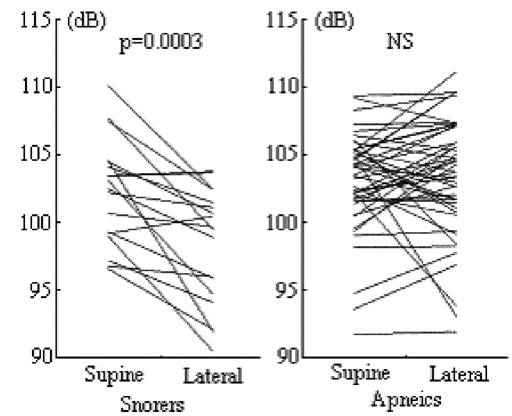

Figure 2—Change in snoring intensity between supine position and lateral position in snorer group and in apneic group.

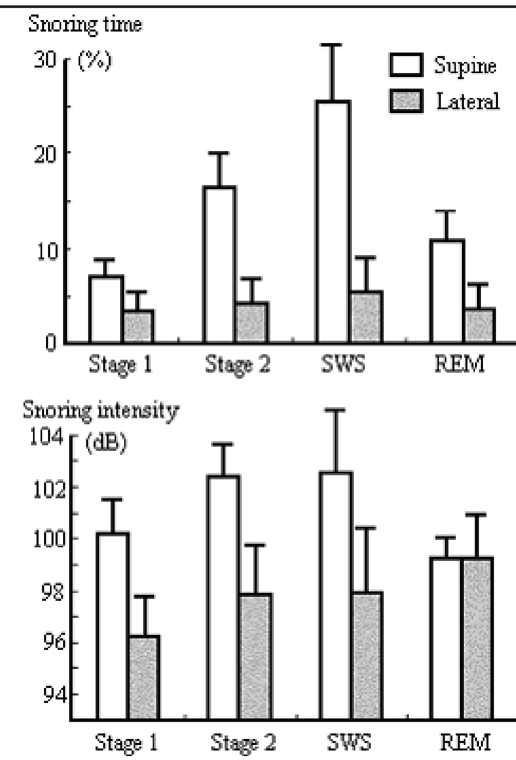

Figure 3—Snoring time and snoring intensity in each sleep stage and body position in snorer group (n=7 for time, n=6 for intensity). Data were expressed as mean ± SE. A two-way ANOVA revealed significant effect of sleep stage (p=0.0218) and position (p<0.0001) on snoring time. It also revealed significant effect of position on snoring intensity (p=0.0073). There was no interaction between sleep stage and position. Both of snoring time and intensity were lower in the lateral position than in the supine position (p<0.01). Snoring time was significantly greater in slow wave sleep (SWS) (p<0.05) than in stage 1 sleep. REM, rapid eye movement.

There are several possible causes for the failure of the apneic group to decrease snoring in the lateral position. First, the decrease in apnea time in the lateral position could have resulted in the increased snoring time. If this was the major cause, the positional change in AHI should have inversely correlated with the positional change in snoring. As opposed to it, in this study the positional change of the snoring did positively (intensity) or insignificantly (time) correlate with the positional change in AHI. Second, it is quite possible that during the obstructive breathing events in the lateral position airflow might be barely preserved enough to generate snoring sound. Third, it is known that pharyngeal shape of OSA patients is characterized by reduced size of lateral diameter,[15] and that the lateral position can cause further reduction in lateral diameter.[7] Therefore it is possible that lateral position causes reduced pharyngeal cross-sectional area, which results in increased snoring in some of the OSA patients. The fact that in some OSA patients in this study snoring increased not only in time, but also in intensity, might support this hypothesis because the intensity of snoring is reported to be positively correlated with the amplitude of intraesophageal pressure swing.[16] To elucidate the mechanism, further study—including the monitoring of esophageal pressure and /or upper airway dimension—is necessary.

The Effect of Sleep Stage on Snoring

In both of apneics and snorers, two-way ANOVA revealed that sleep stage had effects on snoring independently of body position. Snoring was most prominent in slow wave sleep, followed by stage 2, and was least in stage 1 or REM sleep. This finding is compatible with the reports of Lugaresi,[17] Perez-Padilla et al[18] and Hoffstein et al,[19] which described that snoring was most prominent in slow wave sleep, and with the report of Wiegand et al,[20] which demonstrated that upper airway resistance was highest in slow wave sleep. But these reports didn't take into account the effect of body position. Our study makes these descriptions more definite in regard to this point.

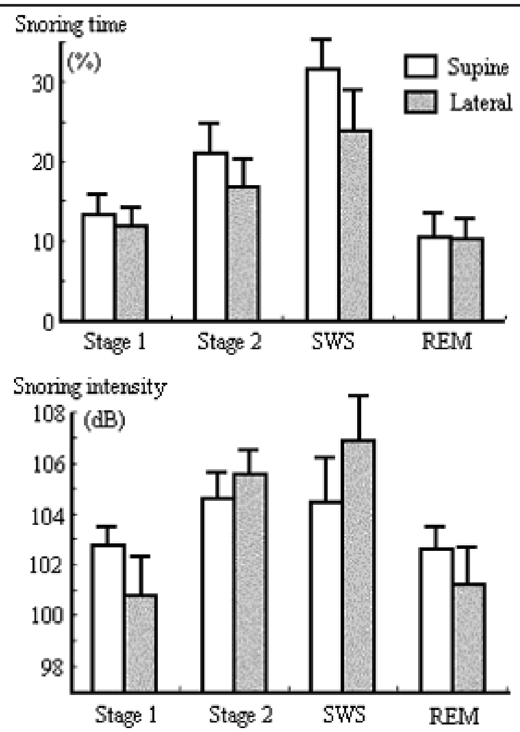

Figure 4—Snoring time and snoring intensity in each sleep stage and body position in the apneic group (n=7 for time, n=6 for intensity). Data were expressed as mean ± SE. Two-way ANOVA revealed significant effect of sleep stage on snoring time ($p<0.0001$) and on snoring intensity ($p=0.0073$). Neither body position nor the interaction between sleep stage and position had any significant effect on snoring intensity or time. Snoring time was significantly greater in slow wave sleep (SWS) than in stage 1 ($p<0.01$), stage 2 ($p<0.05$), or rapid eye movement (REM) sleep ($p<0.01$), and it was significantly less in REM sleep than in stage 2 sleep. Snoring intensity was significantly greater in SWS than in stage 1 and REM sleep ($p<0.05$).

Clinical Implication

The clinical implication of the present study is that the favorable effect of positional therapy on snoring is expected in nonapneic snorers but not always in OSA patients. As mentioned above, one study has already suggested that positional therapy is ineffective for snoring,[13] but the study didn't discriminate between apneic and nonapneic snorers. Therefore further study about positional therapy on nonapneic snorers may be warranted. Another clinical aspect is that the positional dependency of snoring may be one of clinical measures of severity of OSA. Positional snorers may have milder disease and nonpositional snorers may have more severe disease.

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