

Relations Between Sleep Stage, Posture and Effective Nasal CPAP Levels in OSA

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Summary: A retrospective analysis of positional data from 100 male patients with obstructive sleep apnea (OSA) was conducted to determine whether or not 1) the degree of positional dependency was similar in rapid eye movement (REM) compared to non-REM (NREM) sleep, 2) positional dependency correlated with effective levels of nasal continuous positive airway pressure (CPAP) and 3) patients with positional OSA preferentially avoided sleeping in the supine position. The apnea-hypopnea index (AHI) was scored separately for sleep state (NREM and REM) and for posture [off back (AHI-O) and on back (AHI-B)]. The ratio of AHI-O/AHI-B was used to define positional OSA as $\text{AHI-O/AHI-B} \leq 0.50$ (P group) and nonpositional OSA as $0.50 < \text{AHI-O/AHI-B}$ (NP group). A group of 31 patients who had sufficient sleep time in NREM and REM sleep in both sleep postures was selected. In this group 9 out of 22 subjects who showed positional dependency during NREM sleep became nonpositional during REM sleep ($0.05 < p < 0.10$). The mean effective nasal CPAP level was slightly, but significantly, lower in the P group than in the NP group (8.0 versus 9.1 cm H₂O; $p < 0.05$). In addition, a correlation between AHI and effective nasal CPAP levels was found ($r = 0.491$; $p = 0.0001$). The P group had less supine sleep time (SST) than the NP group (32% versus 45% of total sleep; $p < 0.005$). We conclude that 1) 41% of the patients with positional OSA loose positional dependency during REM sleep, 2) patients with nonpositional OSA will require slightly greater levels of nasal CPAP and 3) patients with positional OSA spend less time sleeping supine. **Key Words:** Sleep apnea—Sleep position—Nasal CPAP.

The importance of the relationship between sleep apnea and sleep posture has been emphasized in the past. It has been shown that body position affects the apnea-hypopnea index (AHI) of many, but not all, patients with obstructive sleep apnea (OSA) (1-3). Cartwright and Lloyd categorize patients with sleep apnea into positional and nonpositional groups according to the difference between the AHI in the lateral decubitus and the AHI in the supine sleep position (2,4). They propose to use the ratio of these two parameters for the discrimination of the two groups and to set the cut-off point at 0.50: a value less than or equal to 0.50 indicates a positional effect, whereas in nonpositional sleep apnea this value exceeds 0.50.

In earlier studies the influence of sleep state was not always taken into account. Evidence has been presented that rapid eye movement (REM) and non-REM (NREM) sleep may be different with respect to the manifestation of a positional effect (5,6). It may be that

the positional variation of the AHI is greater during NREM sleep. However, no firm conclusions can be made because of the small number of patients studied so far (3).

The question of whether positional OSA patients are less severely affected than their nonpositional counterpart has been raised before. It has been found that the AHI of the supine sleep position is not significantly different for patients with positional and nonpositional OSA. Therefore, the statement that positional apneics are not necessarily less severe and that they only look less severe because of the positional effect can readily be understood (4).

The perception of a positional influence on the frequency of sleep apneas has given rise to therapeutic approaches enforcing a favorable sleep posture. The aim of sleep position training techniques, such as wearing a position alarm, is to teach the patient not to sleep on the back (7). However, it may be that patients with positional sleep apnea avoid the supine sleep posture spontaneously. Although the possibility of such a spontaneous behavioral adaptation has been mentioned, it has never been substantiated.

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The goal of this retrospective study was to further elucidate these controversial topics. First, we analyzed and compared positional data obtained during NREM and REM sleep. Second, the issue of whether the positional group reflects a less severe category than the nonpositional group in terms of nasal continuous positive airway pressure (CPAP) requirements was addressed. Third, we tested the hypothesis that patients with positional OSA spend less sleep time in the supine position than nonpositionals.

METHODS

Subjects

We reviewed the polysomnographic data of 100 male patients with a discharge diagnosis of OSA, made at the Mayo Sleep Disorders Center between January 1988 and January 1990. The sample was drawn consecutively from an alphabetical patient list. Only the subjects whose polysomnographic study comprised a full night's sleep without therapeutic intervention were included. Patients with previous surgery of the upper airway were excluded.

Polysomnography

Each subject underwent a standard nocturnal polysomnographic study. This included recording the electroencephalogram (C3/A2, C4/A1), electrooculogram, submental electromyogram, electrocardiogram, oxygen saturation with a pulse oximeter (Biox 3700, Ohmeda, Boulder, CO), airflow using nasal-oral thermocouples and thoraco-abdominal respiratory movement (Respirace, Ambulatory Monitoring Inc., Ardsley, NY). These variables were recorded with a multichannel polygraph (Model 8-20D or 78D, Grass Instruments, Quincy, MA).

Sleep was staged in epochs of 30 seconds according to standard criteria (8).

Apnea was defined as a cessation of nasal-oral airflow of at least 10 seconds. Hypopnea was defined as a reduction in nasal-oral airflow of at least 10 seconds, with a concomitant fall in oxygen saturation of at least 2%. The number of apneas and hypopneas per hour of sleep represented the apnea-hypopnea index (AHI).

The diagnosis of sleep apnea syndrome (SAS) was made when the overall AHI was greater than 5. Because elderly people were included in this study, we felt that more than 10 apneas per hour of sleep would be a better criterion for the diagnosis of SAS. Therefore, two patients with an AHI of less than 10 were excluded after the primary data were collected. In all patients the apneas were predominantly of the obstructive type.

Positional scoring and definition of positional categories

Since 1987 the policy in our sleep laboratory has been to score the AHI differentially for sleep state (NREM and REM) and for two body position categories (on back and off back). Body position is essentially determined by observing the patient on a closed-circuit television monitor and by noting each position change directly on the paper record. This allows the determination of the time spent in both postures for NREM and REM sleep. Basically, four positional parameters are derived: the AHI in off back (AHI-O) and on back position (AHI-B) for NREM and REM sleep. Positional data for total sleep are obtained by combining the NREM and REM sleep data.

Prior to setting criteria for the definition of positional categories, two decisions were made. First, the sleep state that most strongly expressed the posture-related differences in AHI was chosen for the demonstration of a positional effect. When the positional data of total sleep were matched with those of NREM and REM sleep, it was clear that NREM sleep was the major determinant of positional dependency. This is not surprising as NREM accounted for 84% of total sleep time in the whole group. Furthermore, as will be pointed out in the Results and the Discussion of this article, NREM and REM sleep are dissimilar with regard to positional dependency. Therefore, it was decided to use the NREM sleep data for the assignment of OSA patients into positional categories. Second, subjects who showed insufficient sleep time in one or both of the studied sleep postures were not included in the statistical analysis. It was argued that too little sleep time in the supine and/or lateral decubitus position would impair a reliable assessment of positional dependency.

TABLE 1. Distribution of sleep time in the two posture categories during NREM and REM sleep

Time (minutes)	NREM sleep ^a		REM sleep ^a	
	On back (n = 98)	Off back (n = 98)	On back (n = 98)	Off back (n = 98)
0-0.9	0	0	37	8
1-4.9	1	0	7	4
5-9.9	4	0	8	5
10-14.9	2	0	6	4
15-19.9	3	0	6	4
20-29.9	7	0	16	12
30-44.9	10	2	9	19
45-59.9	13	1	5	22
60-74.9	12	2	2	14
75-89.9	4	3	1	3
90-104.9	7	0	1	2
105-119.9	5	7	0	1
≥120	30	83	0	0

^a The values in these columns represent the number of patients who spent a corresponding amount of NREM and REM sleep time in each of the positional categories.

TABLE 2. Anthropometric and polysomnographic data for positional and nonpositional OSA patients

	Positional group (n = 49)		Nonpositional group (n = 30)		t test comparison (p value)
	Mean	SD	Mean	SD	
Age (years)	54	13	51	11	NS
Weight (kg)	107	25	114	25	NS
Height (m)	1.75	0.07	1.74	0.09	NS
BMI (kg/m ²)	35	8	38	9	NS
TST (minutes)	340	77	327	76	NS
Stage 1-2 (%TST)	71	11	77	11	<0.05
Stage 3-4 (%TST)	13	9	8	8	<0.05
NREM sleep (%TST)	83	6	85	8	NS
REM sleep (%TST)	16	6	16	8	NS
SST (%TST)	32	16	45	21	<0.005
Overall AHI	45	27	67	20	<0.0005
AHI-O (NREM)	22	22	67	26	=0.0001
AHI-B (NREM)	89	45	77	29	NS
nCPAP (cm H ₂ O)	8.0	2.2	9.1	1.8	<0.05

BMI, body mass index; TST, total sleep time; SST, supine sleep time; AHI, apnea-hypopnea index; AHI-O, apnea-hypopnea index off back; AHI-B, apnea-hypopnea index on back; nCPAP, nasal continuous positive airway pressure; NS, not significant.

Table 1 shows the distribution of the time spent in both position categories for NREM and REM sleep states. For NREM sleep, the 17 patients who had less than 30 minutes of sleep in the supine position were excluded from analysis. For REM sleep, patients who had less than 10 minutes of sleep in each position were excluded. During REM sleep, 47 subjects spent less than that amount of time in the supine position, 12 in the off back, and 5 in both positions. Thus, most subjects who failed to meet the selection criteria had insufficient sleep time on the back, either in NREM or in REM sleep. This may introduce a potential bias toward selection of patients with nonpositional OSA, as some patients with positional OSA spontaneously avoid sleeping on the back. Combination of the NREM and REM criteria restricted the number of evaluable patients to 33 (64 patients had insufficient REM sleep and 1 patient had insufficient NREM sleep).

The definition of positional classes was based on the ratio between AHI-O and AHI-B. Patients were assigned to the positional group when AHI-O/AHI-B \leq 0.50. If $0.50 < \text{AHI-O/AHI-B} \leq 2$, they were regarded as being nonpositional. Thus, even if the AHI in the off back position was up to two times greater than the AHI in the supine sleeping position, patients were still classified in the nonpositional group. Only when this ratio was greater than 2 was the possibility of a reverse positional effect considered.

Of the original sample of 98 patients with an AHI of more than 10, 81 patients had more than 30 minutes of NREM sleep in both positions. According to our definition of NREM positional categories, 49 subjects (60.5%) were positional, 30 (37%) were nonpositional and 2 (2.5%) were reverse positional. In REM sleep 16 out of 33 (48.5%) patients were positional, 15 (45.5%) were nonpositional and 2 (6%) were reverse positional.

Being very few in number, the reverse positional patients were not studied any further. Thus, 79 patients were included in the evaluation of NREM sleep. To compare positional dependency in NREM and REM sleep states 31 subjects were selected. Forty-two position-dependent OSA patients with sufficient REM sleep off back were also chosen to compare AHI-O during REM sleep relative to NREM sleep.

Determination of effective nasal CPAP level

Patients in whom the diagnosis of OSA was made returned for a second overnight sleep study. On that occasion nasal CPAP was titrated up to a level that eliminated sleep-disordered breathing events and snoring in the supine position. Effective nasal CPAP levels in the off back position were not assessed separately.

Statistical analyses

Both sleep states and positional categories were compared by paired or unpaired, two-tail *t* tests. To assess correlation of parameters single linear regression analysis was carried out. McNemar's chi-square test was used to compare positional dependency during NREM and REM sleep. All calculations were performed on a Macintosh SE microcomputer, using statistical and graphical programs (Statview 512+, Brainpower Inc., Calabases, CA; Cricket Graph V1.2, Cricket Software, Malvern, PA).

RESULTS

Table 2 shows the anthropometric and polysomnographic data for the two groups. No statistically sig-

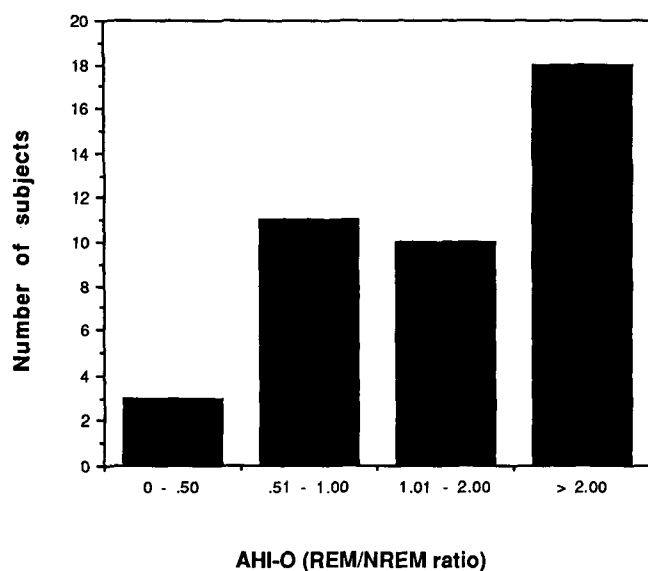


FIG. 1. Relation between nonsupine apnea-hypopnea indices (AHIO) assessed during REM and NREM sleep. The ratio of these indices is categorically presented for 42 patients with position-dependent OSA during NREM sleep.

nificant differences were found for age, weight, height or body mass index (BMI). The nonpositional group was slightly heavier than the positional group, which is in keeping with a previous report that a higher degree of obesity is found in nonpositional OSA (2).

Patients in the positional category generally had a better quality NREM sleep, with less stage 1-2 and more stage 3-4 sleep. Total sleep time (TST) as well as percent NREM and percent REM sleep were the same in both groups.

As a consequence of a higher AHIO, the mean overall AHI was 49% higher in nonpositional OSA patients. Indeed, there was no significant difference in AHI-B between positional and nonpositional groups, indicating that the severity of sleep-disordered breathing in the supine position was similar.

For comparison of positional dependency between NREM and REM sleep the data for the 31 patients who showed either a positional or a nonpositional ef-

TABLE 3. Comparison of positional dependency in NREM and REM sleep in 31 patients with adequate observation time in both sleep states and positional categories

	Positional effect in NREM sleep (n = 22)	No positional effect in NREM sleep (n = 9)
Positional effect in REM sleep (n = 16)	13	3
No positional effect in REM sleep (n = 15)	9	6

McNemar's chi-square = 3.0; $0.05 < p < 0.10$.

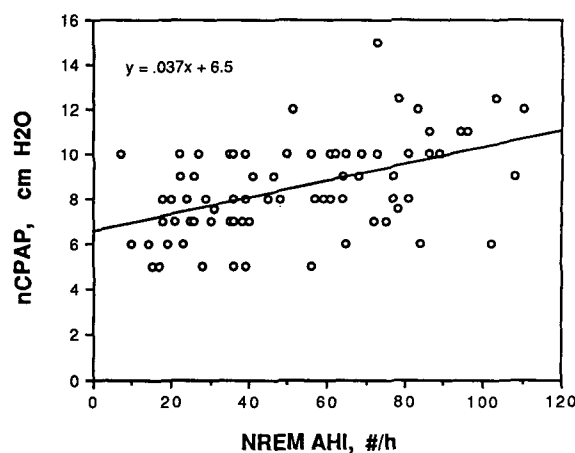


FIG. 2. Correlation of the apnea-hypopnea index in NREM sleep (NREM AHI) and the effective nasal CPAP level (nCPAP) in all patients. $r = 0.491$, $p = 0.0001$.

fect, and who had sufficient sleep time in both sleep states and posture categories, were used. Table 3 shows the number of subjects in each positional category for NREM and REM sleep. In 9 out of 22 patients (41%) positional dependency, present during NREM sleep, was lost during REM sleep. Only 3 out of 16 patients (19%) with a positional effect during REM sleep were nonpositional during NREM sleep. Thus, positional dependency was more predominant during NREM sleep in comparison with REM sleep, and this tendency was nearly significant ($0.05 < p < 0.10$). AHIO is the main discriminator for the presence or absence of a positional effect. Figure 1 represents the REM/NREM AHIO ratio in 42 subjects with positional dependency during NREM sleep. In 28 of the 42 subjects (67%) the REM/NREM AHIO ratio was greater than 1.00, with 18 subjects (43%) having a ratio greater than 2.00.

The mean difference in effective nasal CPAP level between OSA groups was relatively small (1.1 cm H₂O) but statistically significant ($p < 0.05$) (Table 2). Patients with positional sleep apnea required less positive airway pressure for the maintenance of a patent pharyngeal airway during sleep than the nonpositionals. In addition, it was found that the level of nasal CPAP was correlated to AHI for NREM sleep ($r = 0.491$, $p = 0.0001$) (Fig. 2), as well as for total sleep ($r = 0.475$, $p = 0.0001$) in the total group of patients. This correlation was even better in the positional subgroup ($r = 0.551$, $p = 0.0001$) but was not present in the nonpositional subgroup ($r = 0.164$, $p = 0.395$).

Another significant difference between the positional and the nonpositional group was the supine sleep time, expressed as a percentage of TST [SST(%TST)] (Table 2, Fig. 3). The average SST(%TST) was significantly less for the positional than for the nonpositional group (32% versus 45%; $p < 0.005$). A weak, negative cor-

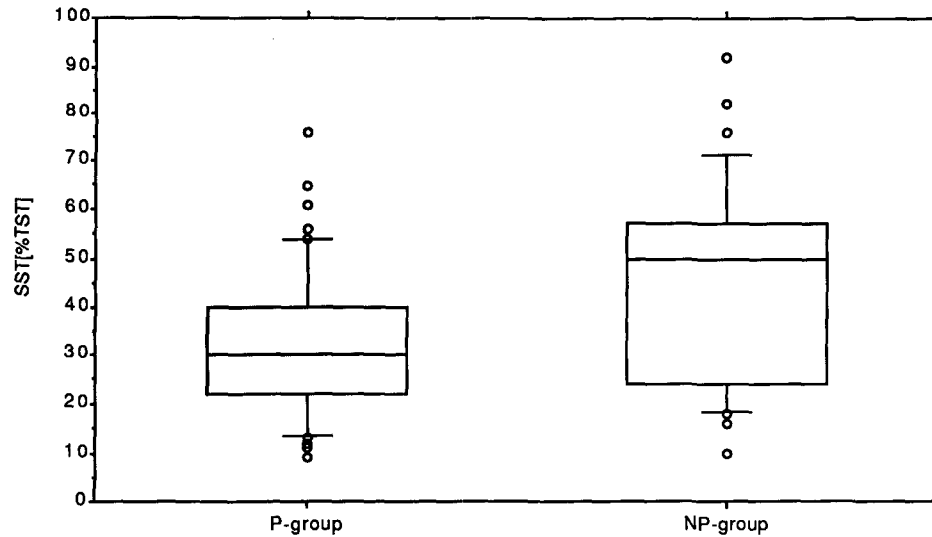


FIG. 3. Comparison of the supine sleep time as a percentage of total sleep time [SST(%TST)] between the positional and nonpositional group (P group and NP group). The horizontal lines in the plot represent the 10, 25, 50, 75 and 90th percentiles. $p = 0.005$.

relation between AHI-B and SST(%TST) was present in the positional group ($r = -0.293$, $p < 0.05$). In other words, patients with positional OSA tended to avoid sleeping on the back in direct proportion to the severity of their OSA in that position. In comparison, no such correlation was evident in the nonpositional group ($r = -0.201$, $p = 0.296$).

DISCUSSION

The results of this study lend support to the hypothesis that the postural variation in AHI is different for NREM and REM sleep states. In a study of seven obese OSA patients George et al. reported that the increase in AHI on the back relative to AHI on the sides was only evident in NREM sleep (5). In the present study the majority of the subjects had very little or even no REM sleep time in one or both of the sleep postures studied—least in the supine position. In fact, this finding is not uncommon and has been reported by other investigators. In a recent study Cartwright et al. documented that 11 out of 20 positional OSA patients had no REM sleep on the back (6). The limited information available for REM sleep clearly compromises its comparison with NREM sleep. Still, when subjects who spent more than 10 minutes in each sleep position during REM sleep were selected, it was found that 41% of the patients with positional dependency during NREM sleep lost this positional effect during REM sleep. In addition, AHI-O increased more than twofold during REM sleep relative to NREM sleep in 43% of the patients with positional OSA. It may be that atonia of upper airway muscles during REM sleep accounts for the loss of this positional effect. Abolition

of dilator muscle tone facilitates additional narrowing and eventually collapse of the upper airway, even in the nonsupine position.

The patients with position-dependent OSA required lower levels of nasal CPAP for effective treatment than did patients with nonpositional OSA. Although the difference was statistically significant, it was quantitatively small (1.1 cm H₂O). This difference was expected to be larger, as it was presumed that positionals have less severe OSA than nonpositionals. However, it is logical that such a small difference was found when one considers 1) that nasal CPAP was titrated to an effective level in the supine position and 2) that AHI on back was comparable in both groups. Unfortunately, no data were available to compare both groups for nasal CPAP differences in the off back position. The significant correlation between AHI and nasal CPAP indicates that a higher level of nasal CPAP is needed for effective treatment of patients with more severe OSA.

It has been emphasized in the literature that positional scoring of the AHI is clinically important. This is because patients whose sleep apnea is predominantly related to the supine sleep posture are likely to benefit from sleep position training (7). Furthermore, it has been proposed to try and convert nonpositional into positional OSA by means of weight reduction or uvulopalatopharyngoplasty, and then to focus on positional therapy (4,9). Two findings in the present study suggest that this therapeutic concept should not be accepted without caution. First, patients with positional sleep apnea have less SST than those without a positional effect. They also show a tendency to have less SST when their supine position-related AHI is high.

It is plausible that these patients have spontaneously learned to avoid sleeping on the back. From this perspective one might expect that the benefit of additional sleep position training is more limited. Second, an NREM sleep-related positional effect may be lost in REM sleep. It is common to observe that OSA patients, who are perfectly positional in NREM sleep, show a high AHI during REM sleep in the lateral decubitus position. Whether to choose between conservative positional treatment or more invasive therapy, comprising nasal CPAP and/or surgery of the upper airway, should not be based on the mere presence or absence of a positional effect, defined by the AHI-O/AHI-B ratio. A careful analysis of the actual AHI-O numbers for both NREM and REM sleep is required for this purpose.

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