ELSEVIER

Sleep Medicine 7 (2006) 281–285

SLEEP MEDICINE

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Brief Communication

# Half of patients with obstructive sleep apnea have a higher NREM AHI than REM AHI

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Received 27 August 2004; received in revised form 19 September 2005; accepted 28 October 2005

**Abstract**

*Background and purpose*: To determine the percentage of sequential patients with obstructive sleep apnea with a higher non-rapid eye movement (NREM) apnea–hypopnea index (AHI) than rapid eye movement (REM) AHI and those with a higher REM AHI than NREM AHI, and to look for factors that might influence the AHI to be higher in one of these two groups versus the other and thus ascertain the factors that cause an AHI to be higher in NREM than REM. A high body mass index (BMI) and a supine body position are well known as exacerbating factors for obstructive sleep apnea (OSA). Males, as well as older individuals, are generally more predominantly affected with OSA than females. Usually OSA is worse in REM sleep than in NREM sleep, although this is not always true.

*Methods*: A retrospective study of sequential patients from one month's admission to a single sleep laboratory was conducted. We determined the age, sex, BMI, body position, duration of apnea, amount of time spent in REM and oxygen desaturation in patients who had a higher NREM AHI than REM AHI versus those who had a higher REM AHI than NREM AHI. To minimize variability, the sleep studies were scored by a single individual.

*Results*: A higher NREM AHI than REM AHI was found in 50% of the 66 patients with OSA. Males predominated in each group and there was no age difference between the groups. Although AHI for both groups tended to become higher with an increase in BMI, the BMI was not statistically different between the two experimental groups. OSA was worse in the supine position in both experimental groups consistent with previous literature. Percentage of time spent in REM or the duration of the apnea did not determine whether a patient fell into the NREM AHI > REM AHI group versus the REM AHI > NREM AHI. The severity of oxygen desaturation was not significantly different between the NREM AHI > REM AHI versus the REM AHI > NREM AHI group. However, when we combined and analyzed the two groups as a whole, the apneas were longer in REM, consistent with previous literature.

*Conclusions*: Although it is well known that OSA is generally worse in REM sleep because of the degree of desaturation and duration of apnea, a higher NREM AHI than REM AHI is found in up to one half of individuals. Most of the usual predictors for severity of OSA as a whole did not discriminate these groups. Further work needs to be done to determine the factors that discriminate these two groups and thus make AHI higher in NREM than REM.


*Keywords:* Obstructive sleep apnea; NREM sleep; REM sleep; Age; Sex; Body mass index; Body position

## 1. Introduction

Obstructive sleep apnea (OSA) is usually worse in rapid eye movement (REM) sleep than non-rapid eye movement sleep (NREM) [1]. It is well known that older age, male sex, higher body mass index (BMI) and supine body position worsen OSA [2,3]. There have been few attempts to determine whether these factors discriminate patients with a higher NREM apnea–hypopnea index (AHI) from those with a higher REM AHI [4]. Loadsman and Wilcox evaluated patients with sleep apnea who were evaluated for potential surgery and found that the NREM AHI was higher than REM AHI in 50% of their patients [4]. Neither age nor BMI was different in those patients with a higher NREM AHI than in those with a higher REM AHI. In their

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doi:10.1016/j.sleep.2005.10.006

study, the minimum saturation was lower in REM sleep in 47% of patients, lower in NREM sleep in 39% of patients and equal in the other 14%. They did not examine the associations with sex, body position, time spent in REM or duration of apnea in their study. Series et al. in 1990 demonstrated that the SaO2 dropped more after an obstructive apnea during REM sleep than during non-REM sleep [5]. Findley et al. concluded that duration of apnea is longer in REM than NREM and the degree of hypoxemia is more severe in REM sleep than NREM sleep [1]. Data from Punjabi et al. shows that REM and NREM RDI are highly correlated and differences between REM and NREM RDI were predominantly in mild subjects with AHI <30/h [6].

In this study, we divided our patients into two groups: those with a higher NREM AHI than REM AHI and those with a higher REM AHI than NREM AHI. We then determined whether any differences existed between these two groups in age, sex, BMI or body position during polysomnography. We also looked to see if the percentage of time spent in REM or duration of apnea or level of oxygen desaturation had any effect making the AHI higher in NREM compared to REM.

## 2. Methods

Data for 88 sequential patients was collected from one laboratory over one month in October of 2003. To minimize scoring bias, a single individual was responsible for the scoring of the polysomnogram. An apnea index of 5/h or an AHI of 10/h was taken as a minimal criterion for sleep apnea. We excluded patients without any REM sleep or without any NREM sleep and patients with sleep efficiency <40%. Twenty patients whose AHI was <10/h were excluded and two patients whose sleep efficiency was less than 40% were excluded.

Sixty-six total sequential patients from a single sleep laboratory (50 males and 16 females; average age: 44.2 years) who were diagnosed with OSA by polysomnography in October 2003 were thus included in the study. All these patients had symptoms of snoring, choking, gasping at night and were sleepy during the daytime. We selected a specific date and took polysomnographic studies of sequential patients for one month and obtained the following data: age, sex, BMI, REM and NREM time and percentage of total sleep time, AHI, REM AHI (AHI when the patient was in stage REM), NREM AHI (AHI when the patient was in stage NREM), AHI supine (AHI when the patient was in supine position), AHI non-supine (AHI when the patient was in non-supine position), AHI supine REM (AHI when the patient was in supine position and stage REM), AHI supine NREM (AHI when the patient was in supine position and stage NREM), AHI non-supine NREM (AHI when the patient was in non-supine position and stage NREM), AHI non-supine REM (AHI when the patient was in non-supine position and stage REM), mean duration of apneas, mean SaO2, min SaO2, min SaO2 in REM and min SaO2 in NREM, mean duration of REM apneas and mean duration of NREM apneas. Sleep stages and respiratory events were defined by the standard criteria [7]. Apnea was defined as a complete cessation of airflow for at least 10 s, and hypopnea was defined as a reduction in airflow that was at least 10 s in duration and was associated with an electroencephalographic arousal or a drop of 3% or more in oxygen saturation [8].

Patients were divided into two groups: patients with NREM AHI greater than REM AHI were placed in the NREM AHI > REM AHI group, and the patients with REM AHI greater than REM AHI were placed in the REM AHI > NREM AHI group. The age, sex, BMI and body position, the time spent in REM, duration of apnea and level of oxygen desaturation were determined in these two groups. We then determined if there were differences in these parameters between the two groups. A possible concern raised was whether it is possible that an individual would more likely be assigned to the REM AHI > NREM AHI group than NREM AHI > REM AHI group on the basis of chance alone due to potentially small differences between REM AHI and NREM AHI. We therefore calculated the absolute average difference in AHI between NREM AHI and REM AHI in the two groups. The results showed this difference was NREM AHI > REM AHI = 21.8 (range = 5.4–33.7/h) and REM AHI > NREM AHI group = 20.6 (range = 8.1–38.7/h). Because the difference between NREM AHI and REM AHI was large and comparable in the NREM AHI > REM AHI and the REM AHI > NREM AHI groups it appears unlikely that patients were assigned differentially to the REM group versus the NREM group based on chance alone. In addition, there were only two patients in the NREM AHI > REM AHI group and one patient in the REM AHI > NREM AHI group whose REM time was less than 10 min making it unlikely that REM AHIs were artificially inflated by short REM time.

## 3. Results

Half of the patients had a higher NREM AHI than REM AHI and the other half had a higher REM AHI than NREM AHI. Subsequent results were consistent with the fact that we artificially dichotomized our patients into those with higher NREM AHI and those with a higher REM AHI (Table 1). As expected, the total AHI was generally higher in the group with higher NREM AHI than REM AHI. This is simply an artifact as the bulk of the normal sleep period is approximately 80% NREM sleep. However, the ratio of NREM AHI/REM AHI in the NREM group was comparable to the ratio of REM AHI/NREM AHI in the REM group (Table 2).

The average age of patients with a higher NREM AHI than REM AHI was 45.60 years (M = 45.3 years, F = 47.6

Table 1
Relation of age, sex, body mass index and body position to sleep stage distribution—NREM/REM

| | NREM AHI > REM AHI, 50% | | | REM AHI > NREM AHI | | |
|---|---|---|---|---|---|---|
| | Male | Female | M and F | Male | Female | M and F |
| No. 66 | 28 | 5 | 33 | 22 | 11 | 33 |
| Age range | 45.3 (23–80) | 47.6 (37–60) | 45.6 (23–80) | 44 (28–64) | 54.2 (38–65) | 47.4 (28–65) |
| BMI range | 34.3 (25.5–51.4) | 39.3 (32–53.2) | 35.0 (25.5–53.2) | 35.2 (26.5–57.1) | 34.5 (22.4–48.8) | 35.0 (22.4–57.1) |
| Stage REM % of TST | 15.2 | 12.2 | 14.7 | 16.3 | 14.3 | 15.6 |
| AHI/h | 54.3 | 54.5 | 54.3 | 30.3 | 23.2 | 27.9 |
| NREM AHI/h | 58.4 | 57.1 | 58.2 | 27.0 | 20.1 | 24.7 |
| REM AHI/h | 37.1 | 30.0 | 36.0 | 47.1 | 45.3 | 46.5 |
| AHI supine/h | 56.4 | 56.3 | 56.4 | 33.7 | 28.1 | 31.8 |
| AHI non-supine/h | 46.8 | 58.9 | 48.6 | 19.3 | 18.1 | 18.9 |
| AHI supine NREM/h | 58.2 | 58.3 | 58.2 | 29.7 | 25.6 | 28.3 |
| AHI supine REM/h | 36.7 | 18.4 | 33.9 | 44.4 | 36.0 | 41.6 |
| AHI non-supine NREM/h | 47.1 | 60.6 | 49.2 | 16.3 | 19.2 | 17.3 |
| AHI non-supine REM/h | 28.9 | 39.5 | 30.5 | 31.7 | 28.1 | 30.5 |
| Mean duration of apneas (s) | 20.46 | 19.60 | 20.33 | 20.41 | 16.55 | 19.12 |
| Mean duration of NREM apneas (s) | 20.25 | 18.60 | 20.00 | 19.23 | 16.64 | 18.36 |
| Mean duration of REM apneas (s) | 24.14 | 25.00 | 24.27 | 23.64 | 18.09 | 21.79 |
| Mean SaO2 | 88.93 | 87.6 | 88.72 | 92.44 | 93.1 | 92.65 |
| Min SaO2 | 72.92 | 70.6 | 72.57 | 80.18 | 82.27 | 80.87 |
| Min SaO2 NREM | 76.35 | 74.4 | 76.06 | 83.17 | 84.90 | 83.47 |
| Min SaO2 REM | 76.23 | 72.8 | 75.70 | 82.40 | 83.67 | 82.87 |

BMI, body mass index; AHI, apnea–hypopnea index; REM, rapid eye movement sleep; NREM, non-rapid eye movement sleep; TST, total sleep time.

years). The average age of patients with a higher REM AHI than NREM AHI was 47.39 years (M = 44 years, F = 54.2 years). Females with higher REM AHI than NREM AHI tended to be older, but this difference was not statistically significant (Table 1). The literature generally shows that 2/3 of patients with OSA are males. There was a male predominance in both our experimental groups. There were proportionally more males in relationship to females in the NREM AHI > REM AHI group (28 versus 5 or 84.8%) as opposed to the REM AHI > NREM AHI group (22 versus 11 or 66%), but this result did not quite reach statistical significance ($P = 0.085$) (Table 1).

Consistent with the previous literature OSA in our patients was associated with a high BMI in both our experimental groups. However, there was no statistically significant difference in BMI between patients with a higher NREM AHI versus those with a higher REM AHI, i.e. NREM group—35.02 (M = 34.25, F = 39.28), REM group—35.37 (M = 35.19, F = 34.5). In patients with a higher NREM AHI the females were heavier, but this result did not reach statistical significance (Table 1).

The AHI was higher in the supine position in both groups (Table 2). This is consistent with the literature that sleep apnea is worse in the supine position [3]. The percentage of total sleep time spent in REM was comparable in both groups: NREM AHI > REM AHI = 14.75 versus REM AHI > NREM AHI = 15.65 (Table 1). We also stratified the data on the basis of severity: mild apnea 5–19/h, moderate apnea 20–50/h and severe apnea > 50/h (Table 3). Looking at the stratified data, the duration of apnea was found to be comparable in both the group thus proving not to be a factor in contributing to a higher NREM AHI than REM AHI (Table 3). It appeared that the severity of the apnea was not a factor in determining the AHI to be higher in NREM than REM. The overall minimum oxygen saturation was more severe in the NREM AHI > REM AHI group when AHI was in the severe range, > 50/h (Table 3). However, out of 17 patients in this group, the minimum saturation was lower for

Table 2
Ratios of body position to the sleep stages—NREM/REM

| | NREM AHI > REM AHI | | | REM AHI > NREM AHI | |
|---|---|---|---|---|---|
| 1 | NREM AHI/REM AHI | 1.61 | 1 | REM AHI/NREM AHI | 1.88 |
| 2 | NREM AHI supine/NREM AHI non-supine | 1.18 | 2 | NREM AHI supine/NREM AHI non-supine | 1.63 |
| 3 | REM AHI supine/REM AHI non-supine | 1.11 | 3 | REM AHI supine/REM AHI non-supine | 1.36 |
| 4 | AHI supine/AHI non-supine | 1.16 | 4 | AHI supine/AHI non-supine | 1.68 |

AHI, apnea–hypopnea index; REM, rapid eye movement sleep; NREM, non-rapid eye movement sleep.

Table 3
Relation of age, sex, body mass index and body position to sleep stage distribution—NREM/REM: males and females combined

| Male and female avg | NREM AHI > REM AHI | | | REM AHI > NREM AHI | | |
|---|---|---|---|---|---|---|
| | AHI < 20/h | AHI 20–50/h | AHI > 50/h | AHI < 20/h | AHI 20–50/h | AHI > 50/h |
| Number of patients | 5 | 11 | 17 | 17 | 9 | 7 |
| Age range | 42.2 (32–62) | 38.1 (23–60) | 51.47 (36–80) | 49.2 (29–64) | 44.42 (28–65) | 46.85 (40–56) |
| BMI range | 28.64 (25.8–32) | 34.51 (25.5–49.6) | 37.22 (27.1–53.2) | 33.5 (22.4–57.1) | 37.71 (27.1–45.4) | 34.93 (27.1–42.2) |
| Stage NREM (%TST) | 84.12 | 83.95 | 85.34 | 82.59 | 86.41 | 86.29 |
| REM %TST | 15.88 | 15.85 | 14.92 | 17.06 | 14.34 | 15.8 |
| AHI/h | 15.26 | 36.73 | 77.19 | 15.47 | 26.72 | 59.93 |
| REM AHI/h | 10.60 | 19.71 | 54.05 | 34.31 | 49.68 | 71.94 |
| NREM AHI/h | 16.22 | 40.73 | 81.84 | 35 | 22.71 | 57.83 |
| AHI supine/h | 44.94 | 45.47 | 66.74 | 21.11 | 24.65 | 67.18 |
| AHI non-supine/h | 10.66 | 26.53 | 74.03 | 9.66 | 21.54 | 37.75 |
| AHI supine REM/h | 30.14 | 20.4 | 33.52 | 33.36 | 34.39 | 70.75 |
| AHI supine NREM/h | 44.98 | 47.63 | 69 | 15.67 | 21.9 | 66.45 |
| AHI non-supine NREM/h | 12.68 | 20.82 | 78.24 | 7.16 | 22.69 | 34.65 |
| AHI non -supine REM/h | 9.56 | 12.26 | 48.47 | 21.27 | 32.18 | 50.83 |
| Mean duration of apneas (s) | 18.80 | 17.64 | 22.58 | 18.47 | 17.00 | 23.43 |
| Mean duration of apnea NREM (s) | 19.00 | 17.82 | 21.71 | 17.71 | 16.56 | 22.29 |
| Mean duration of apnea REM (s) | 20.00 | 21.09 | 27.59 | 19.53 | 21.78 | 27.29 |
| Mean SaO2 | 93.8 | 90.55 | 86.06 | 93.48 | 92.5 | 90.86 |
| Min SaO2 | 84.6 | 73.82 | 68.23 | 83.18 | 78.66 | 78.14 |
| Min SaO2 NREM | 85.6 | 75.73 | 73.47 | 85.8 | 83.55 | 79.00 |
| Min SaO2 REM | 89.2 | 79.45 | 69.32 | 85.7 | 79.88 | 79.85 |

only five patients in NREM. When data was stratified by both sex and severity no new patterns were observed. However, this double-stratified data must be interpreted with caution because of the smaller number of patients in these subgroups (data not shown).

We would emphasize that some of our results can be a manifestation of our experimental groups, i.e., we artificially divided our patients into two groups with the goal of finding the factors discriminating these groups. When we looked at our patients as a whole, we found longer duration of apnea in REM sleep consistent with previous literature (Table 4) [1,5]. However, minimum desaturation did not differ in REM versus NREM sleep for the combined groups (Table 4).

There were no differences in comorbidities for other medical conditions between the NREM and REM groups. In the NREM group, six patients had one or more comorbidities including three cases of chronic obstructive pulmonary disease (COPD), one of emphysema, two of coronary artery disease and three of hypertension. In the REM group, eight patients had one or more comorbidities, including two cases of COPD, one of emphysema, two of asthma, one of pulmonary embolism, one of coronary artery disease, two of atrial fibrillation and two of congestive cardiac failure. As could also be expected, since there were no differences in medical comorbidities between the NREM and REM groups, there were also no differences in the medications taken by the patients between the two groups (data not shown).

## 4. Discussion

The main result of this study is that half the patients seen in the laboratory for OSA have a higher NREM AHI than REM AHI despite traditional teaching to the contrary. This confirms the results of Loadsman and Wilcox who also found that exactly one half of their sleep apnea patients had a higher NREM AHI than REM AHI [4]. This was irrespective of the amount of time spent in REM in both groups.

However, ours is the first study to find such a result in the general sleep apnea population as Loadsman and Wilcox examined patients with sleep apnea who were evaluated for potential surgery. Loadsman and Wilcox also looked at age and BMI in their study as possible discriminators of NREM versus REM distribution in their sleep apnea population. In their study, neither age nor BMI was different in those patients with a higher NREM AHI than in those with a

Table 4
Data for patients as a whole

| | |
|---|---|
| Total no. of patients | 66 |
| Mean duration of NREM apneas (s) | 19.1 |
| Mean duration of REM apneas (s) | 23 |
| Mean duration of apneas total (s) | 19.8 |
| Mean SaO2 (overall for entire study) | 90.6 |
| Min SaO2 (overall for entire study) | 76.7 |
| Min SaO2 NREM (%) | 79.9 |
| Min SaO2 REM (%) | 79.3 |

higher REM AHI. The minimum oxygen desaturation was almost as likely to be in NREM as REM sleep in their study. Unlike the study of Loadsman and Wilcox we also looked at sex, body position, time spent in REM and duration of apneas as associated factors. In our study, whether NREM AHI is higher than REM AHI is not affected by age, sex, BMI or body position, time spent in REM or duration of apnea. The only difference we did find was that oxygen desaturation is lower in the NREM AHI > REM AHI group in patients with AHI > 50/h. However, out of 17 patients in this group, the minimum saturation was only lower for five patients in NREM.

As aforementioned, when we combined the groups into one, apneas were of greater duration in REM consistent with the previous literature [1,5]. However, this was not the aim of the study. Overall, the clinical presentations of these patients were the same. The management probably will also remain the same in these groups of patients. We may infer from this data, that the AHI itself alone may not be the sole index to determine the severity of the sleep apnea. The duration of apneas and degree of desaturation may be additional factors.

The fact that exactly 50% of patients in both the study of Loadsman and Wilcox and ours had a higher NREM AHI than REM AHI suggests that the distribution of the AHI is independent of any factors and is exactly the distribution that one would find based on chance alone. However, further work should be done to determine if some factors as yet unknown determine this distribution and make an AHI higher in NREM than REM.

## Acknowledgements

We appreciate the statistical support of Barry H. Cohen, Ph.D. Director, MA Program in Psychology, New York University.

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