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ORIGINAL ARTICLE

Are the adverse effects of body position in patients with obstructive sleep apnea dependent on sleep stage?

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Abstract
Purpose The purpose of the study was to determine if the adverse effect of body position on obstructive sleep apnea (OSA) is worsened during rapid eye movement (REM) sleep and if patients with OSA decrease the time spent supine during REM sleep.
Methods Overnight polysomnography from 80 sequential patients referred to Buffalo VA Sleep Lab for suspected OSA were analyzed with 20 patients in each of the following groups: normal with apnea–hypopnea indices (AHI) <5/h, mild (AHI, 5–< 15/h), moderate (AHI, 15–<30/h), and severe (AHI, >30/h). We used extended Cox models with the Anderson–Gill modification for multiple events with two time varying covariates: sleep stage and body position. Generalized estimating equations with logit link were used to take into account correlated data within each patient for the relation between sleep stage and body position.
Results The hazard ratios for events in REM vs non-REM sleep was significant for the normal, mild, and moderate groups only: 1.71 (95% CI 1.4–2.08), 1.45 (95% CI 1.22–1.73), 1.28 (95% CI 1.1–1.5), respectively. The hazard ratio for events in the supine vs non-supine position was significant for the mild and moderate groups only: 1.25 (95% CI 1.02–1.52) and 1.24 (95% CI 1.04–1.47), respectively. The addition of an interaction effect between sleep stage and body position was not statistically significant for any group. The odds ratios of sleeping in supine position for REM vs non-REM sleep were 0.47 (95% CI 0.27–0.82) for moderate OSA group and 0.54 (95% CI 0.3–0.95) for severe OSA.
Conclusion In summary, we found significant effects of both sleep stage and body position in mild and moderate but not severe OSA. Patients with moderate and severe OSA were less likely to spend time in the supine position during REM compared with non-rapid eye movement sleep.

Keywords Obstructive sleep apnea · REM sleep · Body position

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Introduction

In certain patients with obstructive sleep apnea (OSA), respiratory events occur with increased frequency during sleep in the supine posture [1, 2] and during rapid eye movement (REM) sleep [3] although the latter has been disputed [4]. Apnea–hypopneas are longer in duration and are associated with more hypoxemia during REM sleep [5]. The effect of gravity on the upper airway when adopting the supine posture is the main reason for the anatomical and physiological changes observed in this posture [6]. During REM sleep, increased pharyngeal collapsibility due to generalized muscle atonia along with decreased ventilatory and/or arousal responses to hypoxia, hypercapnia, and upper airway occlusion are likely responsible for the worsening of sleep apnea during REM sleep. We postulated that the muscular atonia that occurs in REM sleep may enhance the adverse gravitational effects on upper airway caliber that are associated with sleeping in the supine body position. Therefore, we anticipated that there may be an interactive effect between the effects of sleep stage and body position on the apnea–hypopnea index (AHI). Previous work, however, has suggested that the difference in AHI between supine and non-supine sleep are either less pronounced [7, 8] or similar [9] during REM sleep compared with non-rapid eye movement (nREM) sleep. Even if only main effects of posture and sleep stage were playing a role, it would alleviate deleterious effects, if patients with OSA decreased the time spent in the supine position during REM sleep. Previous work has suggested that patients with positional OSA spend less time asleep in the supine position than those without positional sleep apnea [8] but the degree to which this preference occurs during REM and non-REM sleep has not been determined. There was no association between REM sleep and body position in normal subjects [10]. We hypothesized that patients with more severe sleep apnea would decrease the time spent in the supine posture during REM sleep. The purpose of this study was two-fold: to determine importance of interaction between the effects of body position and sleep stage and to determine if patients with OSA tend to decrease the time spent in the supine posture during REM sleep. To answer these questions, we studied an equal number of patients with a normal sleep study and mild, moderate, and severe sleep apnea.

Methods

Patient population Consecutive patients were chosen from those undergoing a sleep study at the Veterans Affairs Western New York Healthcare System. The first 20 patients who had a normal study or a study disclosing mild, moderate, or severe obstructive sleep apnea were chosen for analysis. Patient characteristics are shown in Table 1.

Polysomnography Standard overnight polysomnography included recordings of EEG, electro-oculogram, submental and bilateral leg electromyograms, and ECG. Airflow was measured by a nasal pressure transducer (Pro-Tech, Mukilteo, WA, USA) and respiratory effort by thoracoabdominal piezoelectric belts. Measurement of arterial oxyhemoglobin saturation was performed with a pulse oximeter (Nonin 8600 M, Nonin Medical, Plymouth, MA, USA) with the probe placed on the patient's finger. All signals were collected and digitized on a computerized polysomnography system (Sandman, Nellcor Puritan Bennett, Ottawa, Ontario, Canada).

Body position was confirmed by direct observation of the patient by the technician using a low light camera [2]. Each technician was responsible for monitoring of one or two sleeping patients. The camera monitors were placed side by side in the control room to allow simultaneous visualization of the patient's body position. If the technician missed a change in patient posture, they backtracked on the digital recording and placed the posture tag (to denote a change in posture) when gross movement artifact was seen on the sleep record tracings. A videotape recording of the patient synchronized to the sleep digital recording was obtained in all patients. The scoring technician then corrected the record with regards to posture based on the videotape recording.

Sleep stages were scored in 30-s epochs using the Rechtschaffen and Kales sleep scoring criteria [11]. Each epoch was analyzed for the number of apneas and hypopneas. An apnea was defined as the absence of airflow for >10 s. An obstructive apnea was defined as the absence of airflow in the presence of rib cage and/or abdominal excursions, while a central apnea was defined as the absence of airflow and rib cage and abdominal excursions. Events were considered hypopneas when a visible reduction in airflow lasting at least 10 s was associated with either a 4% decrease in arterial oxyhemoglobin saturation or an EEG arousal occurred. An arousal was defined

Table 1 Patient Characteristics

	Normal	Sleep apnea		
		Mild	Moderate	Severe
Age	56.5±10.7	53.1±7.5	58.5±11.0	62.4±11.3[a]
Male/female	18/2	18/2	19/1	20/0
BMI	35.7±6.8	32.9±6.0	31.1±3.5	36.5±5.8[a]
Epworth score	12.3±5.5	13.6±5.8	11.0±4.5	12±6.9
AHI (events/h)	2.1±1.3	9.0±2.4	20.5±3.9	55.3±23.8[a]

Data expressed as mean±standard deviation

[a] Significant difference between groups by analysis of variance

according to the criteria proposed by the Atlas Task Force [12]. The AHI was defined as the number of apneas and hypopneas per hour of sleep. A sleep study finding for OSA was considered positive when the AHI was ≥5/h [13]. As recommended by the American Academy of Sleep Medicine task force, the severity of sleep apnea was classified using the AHI; mild sleep apnea was defined as an AHI of 5–<15/h, moderate sleep apnea as an AHI of 15–30/h, and severe sleep apnea as an AHI>30/h [13]. Patients were classified as being either in the supine or non-supine posture (prone or lateral).

Data analysis The relation between respiratory events and sleep stage and body position was analyzed using an extended Cox model with Anderson–Gill modification for multiple events with two time-varying covariates. For this analysis, sleep stage was coded a 1 for REM sleep and −1 for nREM sleep and 1 for sleep in supine position and −1 for sleep in non-supine positions. To determine the relation between sleep stage and body position, generalized estimating equations with Logic link and exchangeable correlation matrix were used to take into account correlated data within each patient. For this analysis, sleep stage was coded a 1 for REM sleep and 0 for non-REM sleep and 1 for sleep in supine position and 0 for sleep in non-supine positions. A *p* value less than 0.05 was considered significant.

Results

The vast majority of patients were male (Table 1). There were modest differences between groups in BMI and age (Table 1). The effects of sleep stage are shown in Fig. 1. The AHI was significantly increased during REM sleep compared to nREM sleep in patients with a normal sleep study; hazard ratio 1.71 (95% CI 1.4–2.08) and those with mild 1.45 (95% CI 1.22–1.73) and moderate sleep apnea 1.28 (95% CI 1.1–1.5) but not severe sleep apnea. The effects of body position are shown in Fig. 2. The AHI was significantly increased during supine compared with non-supine sleep in patients with mild; hazard ratio 1.25 (95% CI 1.02–1.52) and moderate sleep apnea 1.24 (95% CI 1.04–1.47) but not those with severe sleep apnea or those with a normal sleep study. There was no interactive effect between sleep stage and body position for any group, indicating that only main effects of sleep stage and body position were important.

The odds ratio of the supine posture during REM vs non-REM sleep (averaged over time) is shown in Fig. 3. Patients with moderate and severe sleep apnea but not mild sleep apnea spent significantly less time supine during REM sleep than during non-REM sleep. The odds ratios of supine sleep (REM vs non-REM) were 0.47 (95% CI 0.27–0.82) for moderate sleep apnea and 0.54 (95% CI 0.3–0.95) for severe sleep apnea, respectively.

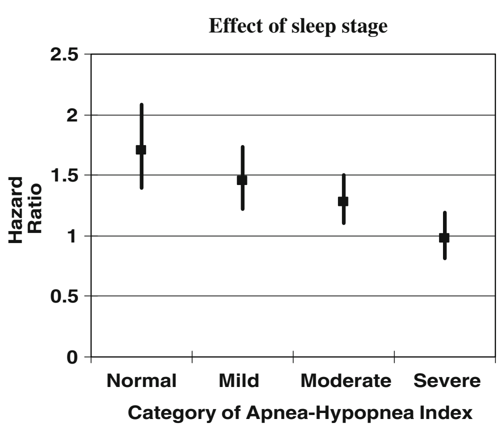

Fig. 1 The effects of sleep stage (REM compared to nREM) on the AHI is shown (hazard ratio calculated REM to nREM). The AHI was significantly increased during REM compared with nREM sleep in normal subjects and patients with mild and moderate sleep apnea

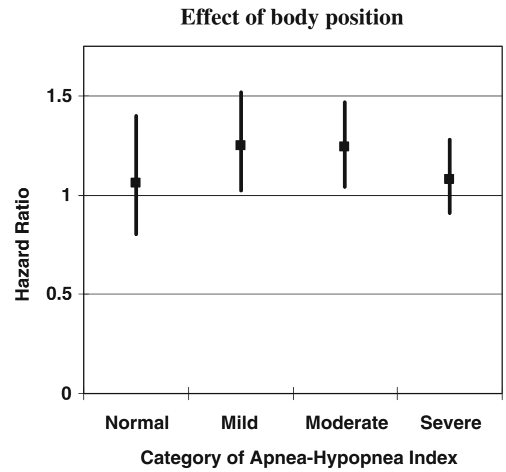

Fig. 2 The effects of body position (supine compared to non-supine) on the AHI is shown (hazard ratio calculated supine to non-supine). The AHI was significantly increased in the supine posture in patients with mild and moderate disease

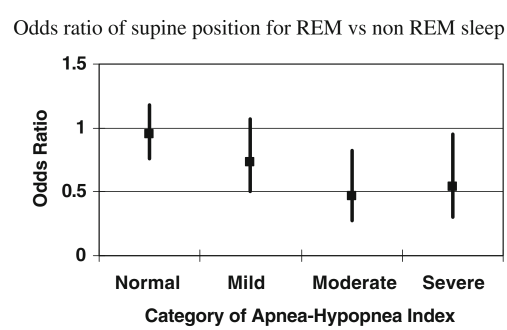

Fig. 3 Odds ratio of supine position for REM vs non-REM sleep. Patients with moderate and severe sleep apnea but not mild sleep apnea spent less time supine during REM sleep than during non-REM sleep

Discussion

It is well established that sleep apnea is worse in the supine posture (1) and during REM sleep [5]. The interaction between sleep stage and body position is less clear. In an early small study of patients with severe sleep apnea, the effects of position on AHI were mild and only seen during nREM sleep [7]. These results are consistent with our data as the effects of sleep stage and position on AHI are only significant in patients with mild and moderate sleep apnea. The AHI in patients with severe sleep apnea was not significantly affected by either factor. Similarly, Punjabi and colleagues found an increased REM AHI compared to the nREM AHI only in patients with an AHI less than 30/h [3]. Two other studies attempted to address the effect of position during REM sleep with conflicting results [8, 9]. This likely reflects the merging of patients with severe sleep apnea with those with milder disease and the relatively modest number of patients studied. It is for this reason that we designed our study with an equal sample of patients with mild, moderate, and severe disease and used sophisticated statistical techniques to isolate the effects of position and sleep stage and their interaction. In our study, only main positional and sleep stage effects were present, and there was no significant interactive effect.

We also examined the time spent supine during REM sleep. Supine sleep was decreased during REM sleep in patients with moderate and severe sleep apnea. Thus, despite the fact that the AHI was not significantly influenced by sleep stage and body position in patients with severe sleep apnea, supine REM sleep was less likely to occur. Prior studies have shown that even if the AHI is not worsened in patients with severe sleep apnea, the duration of the apnea and the severity of oxygen desaturation are significantly worse in the supine posture [14]. Apnea duration and oxygen desaturation is already worse during REM compared to nREM sleep in patients with severe disease [5]. Sleeping in the supine posture further worsens these indices. Thus, there are reasons why avoidance of the supine posture might be advantageous in patients with severe disease. In patients with severe neuromuscular disease, the amount of REM sleep is sharply reduced and often completely absent, likely reflecting the severe hypoventilation that would occur if the patient remained in REM sleep [15]. Patients with severe sleep apnea have disturbed fragmented sleep with reductions in total REM time [3]. Our patients with severe disease also had a reduction in total REM time but the statistical analysis accounted for this reduction and the supine posture was still less likely to occur during REM sleep.

Limitations of our study are that we studied primarily male patients and cannot generalize results for female patients. The small number of female subjects in our study may have increased the variability of our measurements. The sample size for each group was relatively modest, and the vast majority of patients were middle aged or older. Whether these finding apply for younger patients with sleep apnea remains to be determined. We also did not measure Mallampati score, tonsil size, and upper airway dimensions to determine if these factors contribute to the differences between the supine and non-supine posture. Our hypopnea definition required a reduction in flow associated with either arousal or a 4% desaturation as opposed to desaturation alone (Medicare criteria), which could have inflated the AHI in our sample. Nevertheless, the results of our study are internally consistent and agree with the prior literature.

In conclusion, sleep stage and body position affect AHI primarily in patients with mild to moderate sleep apnea. Sleep stage and body position have only main effects on the AHI in patients with mild to moderate sleep apnea. Patients with moderate and severe OSA were less likely to spend time in the supine position during REM sleep.

References

1. Cartwright RD (1984) Effect of sleep position on sleep apnea severity. Sleep 7:110–114
2. Mador MJ, Kufel TJ, Magalang UJ, Rajesh SK, Watwe W, Grant BJB (2005) Prevalence of positional sleep apnea in patients undergoing polysomnography. Chest 128:2130–2137. doi:10.1378/chest.128.4.2130
3. Punjabi NM, Bandeen-Roche K, Marx JJ, Smith PL, Schwartz AR (2002) The association between daytime sleepiness and sleep-disordered breathing in NREM and REM sleep. Sleep 25:307–314
4. Siddiqui F, Walters AS, Goldstein D, Lahey M, Desai H (2006) Half of patients with obstructive sleep apnea have a higher NREM AHI than REM AHI. Sleep Med 7:281–285. doi:10.1016/j.sleep.2005.10.006
5. Findley LJ, Wilhoit SC, Suratt PM (1985) Apnea duration and hypoxemia during REM sleep in patients with obstructive sleep apnea. Chest 87:432–436. doi:10.1378/chest.87.4.432
6. Oksenberg A, Silverberg DS (1998) The effect of body posture on sleep-related breathing disorders: facts and therapeutic implications. Sleep Med Rev 2:139–162. doi:10.1016/S1087-0792(98)90018-1
7. George CF, Millar TW, Kryger MH (1988) Sleep apnea and body position during sleep. Sleep 11:90–99
8. Pevernagie DA, Shepard JW (1992) Relations between sleep stage, posture and effective nasal CPAP levels in OSA. Sleep 15:162–167
9. Cartwright R, Lloyd S (1991) The sleep stage and sleep position effects on the apnea severity in positional patients. Sleep Res 20:218
10. Lorrain D, De Koninck J (1998) Sleep position and sleep stages: evidence of their independence. Sleep 21:335–340
11. Rechtschaffen A, Kales A (1968) A manual of standardized technology, techniques and scoring system for sleep stages of human subjects. Brain Information Service. Brain Information Institute. University of California, Los Angeles

12. The Atlas Task Force (1992) EEG arousals: scoring rules and examples; a preliminary report from the Sleep Disorders Task force of the American Sleep Disorders Association. Sleep 15:173–184
13. [No authors listed] (1999) Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research: the report of an American Academy of Sleep Medicine task force. Sleep 22:667–689
14. Oksenberg A, Khamaysi I, Silverberg DS (2001) Apnoea characteristics across the night in severe obstructive sleep apnoea: influence of body posture. Eur Respir J 18:340–346. doi:10.1183/09031936.01.00038101
15. Arnulf I, Similowski T, Salachas F et al (2000) Sleep disorders and diaphragmatic function in patients with amyotrophic lateral sclerosis. Am J Respir Crit Care Med 161:849–856