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Effect of an Anti-Supine Shirt for Treatment of Supine-related Obstructive Sleep Apnea

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Abstract

Background and Objective: To evaluate the effects of a t-shirt designed to prevent patients from sleeping supine (anti-supine shirt) on the frequency of apneas and hypopneas per hour of sleep (apnea-hypopnea index) in patients with supine-related obstructive sleep apnea.

Methods: Twenty-seven consecutive patients found to have supine-related obstructive sleep apnea on a diagnostic polysomnogram were prescribed an anti-supine shirt and then underwent a follow up polysomnogram while wearing this shirt. We then compared the amount of supine sleep time and apnea-hypopnea index between the baseline and follow-up polysomnograms.

Results: A comparison between the baseline and follow-up polysomnograms revealed that there was no significant difference in total sleep time (from 297.2 ± 76.5 to 289.8 ± 101.6 min, p=0.654), but there was a significant reduction in the amount of supine sleep time while wearing the anti-supine shirt (from 149.2 ± 82.9 to 21.3 ± 52.9 min, p<0.001). This was accompanied by a 55% reduction in the total apnea-hypopnea index (from 23.8 ± 8.0 to 10.7 ± 14.7, p<0.001)

Conclusions: The anti-snore shirt reduced the severity of supine-related obstructive sleep apnea by reducing the amount of time spent sleeping supine.

Keywords: Sleep apnea; Posture; Supine; Positional therapy; Anti-supine shirt

Abbreviations

AHI: Apnea-Hypopnea Index, BMI: Body Mass Index, NREM: Non-Rapid Eye Movement, REM: Rapid Eye Movement

Introduction

Obstructive sleep apnea (OSA) is a common disorder affecting approximately 5 to 10% of the adult population [1,2] Approximately 60% of patients with OSA have a significant postural component in which the frequency of apneas and hypopneas per hour of sleep (apnea-hypopnea index or AHI) is at least twice as high in the supine as in the non-supine position [3-7]. In such patients, the supine position not only increases the AHI, but also increases the degree of associated oxygen desaturation and frequency of brady- and tachyarrhythmias [8].

Some patients experience more apneas and hypopneas while supine because the tongue and soft palate are displaced posteriorly due to the effect of gravity, causing narrowing of the upper airway (UA) [4,5,8]. This combined with a reduction in genioglossus muscle tone at sleep onset increases the propensity for the tongue to relapse into the UA and cause obstruction [6,8-12]. In addition, the nasal mucosa tends to become edematous while in the supine position thereby increasing upstream inspiratory airflow resistance that further increases UA collapsibility [13].

Since OSA is often supine-related, and since continuous positive airway pressure (CPAP) is poorly tolerated by a substantial proportion of patients with OSA [14] therapies have been developed to prevent patients from sleeping supine. Anti-supine interventions include wearing a pyjama top with a tennis-ball sewn onto the back or wearing a belt or shirt with balls or cylinders attached to the back. However, there are few published studies that have evaluated the effects of such interventions on OSA severity. Furthermore, most studies have evaluated a non-standardized commercially unavailable device. Therefore, our study was conducted to assess the effects of a standardized commercially available anti-supine sleep shirt on sleeping position and AHI in patients with supine-related OSA.

Materials and Methods

Subjects

Inclusion criteria were: 1) men and women at least 18 years of age referred to the sleep laboratory because of a clinical suspicion of sleep apnea based on a history of habitual snoring and at least one of nocturnal dyspnea, morning headaches, or excessive daytime sleepiness, 2) supine-related OSA defined as a total AHI of at least 10, 3) an AHI in the supine position at least twice that in the non-supine position, and 4) no previous treatment for OSA.

Polysomnography

All subjects underwent overnight polysomnography (PSG) for an assessment of sleep apnea using standard techniques and scoring criteria for sleep stages and arousals from sleep [15,16]. All subjects slept on a single pillow with the bed flat. Thoracoabdominal motion was monitored by respiratory inductance plethysmography and nasal airflow by nasal pressure cannulae. Arterial oxyhemoglobin saturation (SaO_2) was monitored by oximetry. Apneas were defined as a greater than 90% reduction and hypopneas as a 50% to 90% reduction in airflow from baseline lasting at least 10 sec. They were classified as obstructive if there was out-of-phase thoracoabdominal motion, or airflow limitation on nasal pressure [17]. Sleeping position was determined by video monitoring throughout the PSG. The AHI was quantified. Variables analyzed included total AHI, total sleep time (min), stages N1, N2, N3 and rapid eye-movement (REM) sleep time (min), supine sleep time (min), AHI in supine and non-supine positions, REM and non-REM related AHI, the total arousal index (arousals per hr of sleep), respiratory arousal index (respiratory-related arousals per hour of sleep), and the mean and minimum SaO_2 during sleep.

Protocol

Subjects underwent overnight attended PSG in the sleep laboratory. Those with supine-related OSA with a total AHI ≥ 10 were offered positional therapy with an anti-supine shirt (Rematee AntiSnore Shirt, Vancouver, BC, Canada) consisting of a cotton T-shirt with three styrofoam cylinders inserted in three pouches across the mid-back (Figure 1). These cylinders are designed to prevent patients from sleeping on their back. Subjects who obtained the anti-supine shirt wore it for 2 to 4 weeks at home to allow acclimatization, following which they underwent a second PSG while wearing the anti-supine shirt to assess its effect on sleeping position, AHI, and sleep structure. The protocol was approved by the research Ethics Board of Toronto Rehabilitation Institute, and all subjects provided written consent prior to participation.

Figure 1: Photographs of the anti-supine shirt: rear view (left panel) and side view (right panel) illustrating three pouches on the back of the t-shirt containing cylinders of styrofoam that are designed to keep patients off their backs during sleep.

Statistical Analysis

We compared the sleep variables described above between the baseline and follow-up PSGs using paired t-tests and Wilcoxon-Signed-Ranks test for parametric and non-parametric data, respectively. Correlations were examined using the Pearson correlation coefficient. These variables were analyzed using a statistical package (SPSS version 11.0, Chicago, IL) and data are presented as mean ± SD. A p-value<0.05 was considered significant.

Results

Patient characteristics

Twenty-seven patients, 25 men and 2 women whose characteristics are shown in Table 1, participated. The AHI was much higher supine than non-supine. Figure 2 shows that compared to baseline, supine sleep time decreased significantly while wearing the anti-supine shirt (p<0.001).

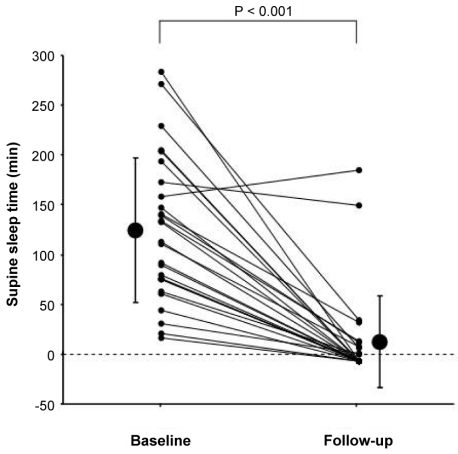

Figure 2: The anti-supine shirt significantly decreased supine sleep time from 149.2 ± 82.9 min at baseline to 21.3 ± 52.9 min at follow-up (P<0.001).

As expected, non-supine sleep time increased while wearing the anti-supine shirt (p<0.001, Table 1). This was associated with a significant (55%) reduction in the AHI (p<0.001, Figure 3) with a significant increase in minimum SaO_2 (p<0.001) but no significant increase in mean SaO_2 during sleep (Table 1).

N=27	Baseline	Follow-up	P-value
BMI (kg/m^2)	27.8 ± 4.0	27.9 ± 3.9	0.127

Total Sleep Time (min)	297.2 ± 76.5	289.8 ± 101.6	0.654
Sleep Efficiency (%)	74.9 ± 17.0	67.9 ± 21.1	0.041
Sleep Onset Latency (min)	17.1 ± 19.3	17.8 ± 26.7	0.904
Supine sleep time (min)	149.2 ± 82.9	21.3 ± 52.9	<0.001
Supine AHI (events/hour)	49.5 ± 23.6	16.4 ± 27.8	<0.001
Non-supine sleep time (min)	145.6 ± 64.1	267.8 ± 100.9	<0.001
Non-supine AHI	10.4 ± 33.6	10.2 ± 14.2	0.171
Total AHI	23.8 ± 8.0	10.7 ± 14.7	<0.001
Total Arousal Index (arousals/hour)	30.3 ± 15.1	27.2 ± 17.7	0.302
Total Respiratory Arousal Index (respiratory arousals/hour)	14.9 ± 7.9	6.3 ± 9.2	0.001
Sleep time in REM (min)	42.6 ± 27.1	49.2 ± 31.2	0.328
Sleep time in NREM (min)	254.6 ± 54.9	241.2 ± 76.7	0.253
Sleep time in N1 (min)	28.0 ± 16.3	23.8 ± 14.4	0.265
Sleep time in N2 (min)	174.9 ± 46.7	171.3 ± 66.5	0.722
Sleep time in N3 (min)	51.7 ± 21.0	46.0 ± 31.3	0.352
Mean O_2 Saturation during sleep	94.1 ± 2.8	94.7 ± 1.6	0.092
Minimum O_2 Saturation during sleep	83.0 ± 6.8	88.3 ± 4.4	<0.001

Table 1: Different characteristics of 27 patients (Values were expressed as mean ± SD).

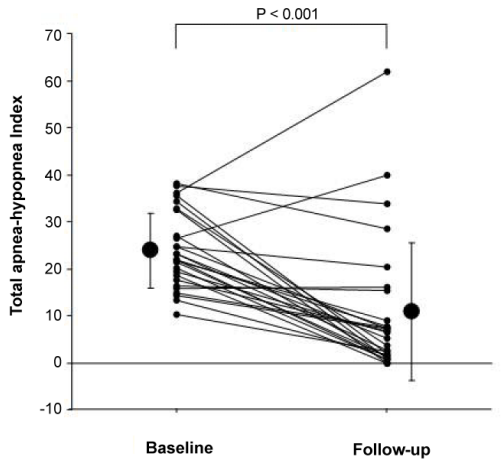

Figure 3: The anti-supine shirt significantly decreased the total AHI from 23.8 ± 8.0 at baseline to 10.7 ± 14.7 at follow-up (P<0.001).

This was not accompanied by any decrease in BMI. The change in the AHI while wearing the anti-supine shirt did not correlate significantly with the change in supine sleep time (r=0.109, p=0.589). Neither total sleep time nor the time in any of the sleep stages changed significantly between the baseline and intervention studies. However, sleep efficiency decreased significantly during the follow-up PSG (p=0.041). The respiratory-related arousal index decreased significantly.

In 20 out of 27 patients, the total AHI fell to less than 10 with the anti-supine shirt indicating virtual abolition of OSA. In this subset of patients, the supine sleep time decreased from 137.3 ± 82.4 to 5.6 ± 11.5 mins (p<0.001) and their AHI decreased from 22.4 ± 7.1 to 3.7 ± 3.1 (p<0.001) in association with an increase in their minimum SaO_2 from 84.4 ± 5.2 to 89.7 ± 3.9% (p=0.003), while mean SaO_2 was unchanged. Similar to the entire group, these 20 patients did not experience any significant change in total sleep time, N3 sleep time or total arousal frequency, and their sleep efficiency tended to decrease (from 72.6 ± 18.4 to 65.8 ± 22.6%, p=0.057). However, in contrast to the entire group, REM sleep time increased significantly from 39.7 ± 27.6 to 48.8 ± 33.2 mins (p=0.024). In 19 patients the AHI fell by greater than 50%. In 17 patients, supine sleep time fell to 0 minutes while wearing the anti-supine shirt. Although in 9 out of the 10 remaining patients supine sleep time fell, in one patient supine sleep time increased (from 187.9 to 218.7 min).

There were three patients in whom the total AHI increased at follow-up. One gained weight between the baseline and follow-up PSG (from 99.8 to 103.4 kg) and had an increase in the non-supine AHI from 7.7 to 40.0 despite complete abolition of supine sleep time (from 175.0 to 0 min). In the second, almost all respiratory events during the baseline PSG occurred during REM sleep while supine. During the follow-up PSG while wearing the anti-supine shirt, many respiratory events remained during REM sleep even though he did not sleep supine so that the REM sleep AHI remained unchanged (from 36.3 to 35.1) while his non-supine AHI increased from 8.2 to 16.0. The third

had severe OSA on the baseline PSG (total AHI of 36.2; supine AHI of 76.3; and non-supine AHI of 2.5) and experienced marked increases in the total AHI to 62.0, supine AHI to 95.2, and non-supine AHI to 60.0 despite a marked reduction in supine sleep time (from 159.6 to 22.1 minute) and without any weight gain.

Discussion

Our study has given rise to two main findings. First, the anti-supine shirt significantly reduced supine sleep time, and second, it significantly reduced the AHI by 55% in association with an increase in the minimum SaO_2 during sleep. However, these changes were not accompanied by any improvement in sleep structure, and indeed there was a slight but significant reduction in sleep efficiency. The reason for this is not clear, but it is possible that discomfort associated with wearing the anti-supine shirt contributed. In addition, the degree of the reduction in AHI did not correlate with the degree of reduction in the time spent sleeping supine. This was because the amount of supine sleep time and the supine AHI varied widely among patients, and in many patients there were still events occurring in the non-supine position that contributed to the total AHI. However, among the subset of 20 patients in whom the AHI decreased to below 10 while wearing the anti-supine shirt, the amount of REM sleep increased significantly, suggesting when the anti-supine shirt abolished OSA, it did cause some improvement in sleep structure.

In approximately 60% of patients, OSA is supine-related [4,18]. However, only a very limited number of studies have evaluated the effects of positional therapy on severity of sleep apnea in such patients, and the anti-supine device used was generally not standardized or commercially available. The effects of these interventions on OSA severity varied widely.

Oksenberg et al. [3] examined the effects of a non-commercially available device consisting of a tennis ball in a pocket sewn onto the back of a belt worn around the chest in 12 patients with supine-related OSA. Patients had PSGs performed before and 2 months after wearing the belt. In association with a decrease in supine sleep time, the AHI decreased from 46.5 ± 19.9 to 17.5 ± 19.4 ($p<0.002$) in association with an improvement in minimum SaO_2. Seven patients (58%) had a reduction in their AHIs to <10. In two patients, supine sleep time did not decrease, and in one of these (8%), the AHI increased similar to the three subjects in our study whose AHI increased while wearing the anti-supine shirt.

Loord et al. [13] tested the effects of another non-commercially available device consisting of a vest with straps attached to a board with a pillow on top making it impossible to lie supine, but allowing movement from side to side. Twenty-three patients had home cardiopulmonary recordings without sleep monitoring before and after wearing the device for three months. The AHI decreased from 21.8 to 14.3 ($p=0.02$). In 13/18 subjects, the AHI decreased and in 11 it decreased to less than 10. However, in five patients (28%) the AHI increased. In addition, five subjects initially dropped out because of discomfort suggesting that it was not as well tolerated as the anti-supine shirt used in our study.

The only randomized trial of anti-supine therapy compared to an untreated control group was an abstract by Barnes et al. [19]. They conducted a four-week randomized trial to test the effects of a non-commercially available anti-supine device on severity of supine-related OSA. The device consisted of a belt worn around the upper chest with a pouch holding a single ball in the middle of the back. In 86 patients with supine-related OSA and a mean AHI of 20.9 ± 9.4, they found that although the device reduced supine sleep time, this was not accompanied by any decrease in the AHI or improvement in subjective sleepiness, quality of life, mood, or cognitive function. It is unclear why the device failed to cause a significant decrease in the AHI similar to that observed in our study.

In another study, 38 patients with a mean AHI of 13 were randomized to a night with a commercially available positional device called the Zzoma Positional Sleeper and a night on CPAP [20]. The positional device decreased supine sleep time from 40% to 0% of total sleep time in association with a significant reduction in median AHI (from 11 to 2, $p<0.001$). However, CPAP caused a greater fall in the median AHI to 0. Compared to our study, in which the AHI fell from 23.8 to 10.7, patients had a much lower AHI. Accordingly, the clinical significance of this reduction in AHI is unclear. Skinner et al. [21] compared a non-commercially available thoracic anti-supine band, to CPAP in a randomized double cross-over trial with one month in each treatment arm using home cardiopulmonary monitoring without sleep recordings. Results were similar to ours with an 82% reduction in supine time and a mean decrease in the AHI from 22.7 to 12.0. However, postural therapy was not as effective as CPAP which reduced the AHI to 4.9. Similar to our study, treatment success, defined as an AHI of <10, was achieved in 13 of 18 (72%) subjects while wearing the anti-supine band.

Jokic et al. [22] also compared the effects of a non-commercially available backpack with a 10 inch soft ball inside to treatment with CPAP in 13 patients with supine-related OSA using PSG. Patients were randomized to two weeks in each treatment group. They reported that positional treatment reduced supine sleep time and caused a reduction in the AHI from 17.9 to 9.5, but CPAP caused a greater fall in the AHI to 3.4.

In summary, with the exception of the abstract of Barnes et al. [19], the above studies reported that the use of a variety of anti-supine devices reduced supine sleep/recording time in association with a reduction in the AHI. The nature of the devices, the severity of the OSA, and the magnitude of the effect of the anti-supine interventions on AHI varied from study to study, indicating inconsistencies among them. Since most of these interventions were neither standardized, nor commercially available, it is difficult to make comparisons among them and to make assumptions about the efficacy of anti-supine interventions in general. The only study besides ours to employ a commercially available anti-supine device was that of Permut et al. [20] in which a thoracic belt was used. However, OSA was very mild in their patients making it difficult to assess the clinical significance of their findings. Our study tested the effects of a standardized, commercially available anti-supine t-shirt. Unlike the anti-supine belts described in most other studies, it is probably more comfortable to wear and should be less likely to slip out of position during the night.

Three patients from our study had an increase in AHI while wearing the anti-supine shirt. In all cases the non-supine AHI increased. In one subject, weight gain between the baseline and follow-up study may have contributed to this increase in AHI. In a second patient, REM-related OSA might have been the main issue rather than supine-related OSA, since OSA on the baseline PSG occurred mainly while in REM during which he was supine throughout. However, in the third patient, the reason for the increase in AHI is not clear, but could simply have been due to spontaneous variability in severity of OSA as previously reported [23-25]. The practical implication of this observation is that one cannot assume that prevention of supine sleep

will cause resolution of OSA in all patients found to have predominantly supine-related OSA on a diagnostic PSG. Therefore, a follow-up PSG while wearing an anti-supine device should probably be performed routinely to ensure that it is effective.

Our study has a few limitations. First, it was not randomized. Nevertheless, the highly significant reductions in supine sleep time and AHI on the anti-supine shirt are most likely due to this intervention since it is designed to prevent lying on one's back and since the results are consistent with those of several previous studies using similar interventions [3,13,20-22]. In addition, because this was designed as a physiological study rather than a clinical trial, we did not assess clinical outcomes such as daytime sleepiness and quality of life.

In conclusion, this study provides evidence that the anti-supine shirt we tested significantly reduces supine sleep time and the AHI: in 20 of 27 patients, it reduced the AHI to <10. Although we did not measure whether this anti-supine shirt reduced patients' symptoms of OSA, some studies that have evaluated anti-supine therapy for OSA reported increased awake time on the maintenance of wakefulness test and reduced Epworth scores, indicating increased alertness and reduced daytime sleepiness [20]. Nevertheless, our study shows that anti-supine therapy does not reduce severity of OSA in all patients with supine-related OSA. Accordingly, when prescribing such therapy, one should consider performing a follow-up PSG on the device to determine whether or not it alleviates OSA. Our study suggests that an anti-supine shirt can be a reasonable alternative to CPAP for the therapy of supine-related OSA, particularly in view of its much lower cost, its convenience, and problems with CPAP compliance. Randomized trials of anti-supine interventions will be required to assess compliance and long-term effects on OSA severity and clinical outcomes.

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