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Official publication of the American College of Chest Physicians



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Chest 2006;130;1772-1778
DOI 10.1378/chest.130.6.1772

The online version of this article, along with updated information and services can be found online on the World Wide Web at:
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ISSN:0012-3692

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Normalization of Memory Performance and Positive Airway Pressure Adherence in Memory-Impaired Patients With Obstructive Sleep Apnea*

Molly E. Zimmerman, PhD; J. Todd Arnedt, PhD; Michael Stanchina, MD, FCCP; Richard P. Millman, MD, FCCP; and Mark S. Aloia, PhD

Background: Although the treatment of obstructive sleep apnea (OSA) with positive airway pressure (PAP) has been shown to be effective, nightly adherence to treatment remains poor. The objective of this study was to examine the degree to which various levels of PAP therapy adherence normalized verbal memory function after 3 months of therapy in patients with OSA who were memory-impaired prior to the initiation of PAP therapy.

Methods: Participants were administered neuropsychological testing prior to the initiation of PAP treatment and at a 3-month follow-up visit. Fifty-eight memory-impaired participants were categorized into the following three groups based on 3 months of adherence to PAP therapy: (1) poor users (n = 14), participants who averaged < 2 h of PAP use per night; (2) moderate users (n = 25), participants who averaged 2 to 6 h of PAP use per night; and (3) optimal users (n = 19), participants who averaged > 6 h of PAP use per night.

Results: Logistic regression analyses revealed that the odds of optimal users exhibiting normalization of memory function following 3 months of PAP therapy were 7.9 times ($p = 0.01$) the odds of poor users exhibiting normalization of memory abilities. Overall, 21% of poor users, 44% of moderate users, and 68% of optimal users exhibited memory performance in the clinically normal range following 3 months of PAP use ($\chi^2 = 7.27$; $p = 0.03$).

Conclusions: These preliminary findings indicate that impaired verbal memory performance in patients with OSA may be reversible with optimal levels of PAP treatment. OSA patients exhibiting verbal memory impairments may experience a clinically meaningful benefit in their memory abilities when they use PAP for at least 6 h per night.

(CHEST 2006; 130:1772-1778)

Key words: adherence; cognition; compliance; memory; obstructive sleep apnea; positive airway pressure

Abbreviations: AHI = apnea-hypopnea index; CI = confidence interval; HVLt-R = Hopkins verbal learning test-revised; OR = odds ratio; OSA = obstructive sleep apnea; PAP = positive airway pressure

Obstructive sleep apnea (OSA) is a common sleep disorder with significant medical and behavioral consequences, including memory difficulties.¹⁻⁸ Positive airway pressure (PAP) is widely considered to be the treatment of choice for OSA,⁹ although nightly adherence to therapy is generally poor.¹⁰⁻¹² PAP has been shown to be a clinically effective treatment for behavioral and medical sequelae of OSA,^{3,13-15} but the amount of PAP necessary to produce a clinically meaningful improvement in memory function is unknown. Few studies have attempted to identify a dose-response relationship

between PAP use and a clinical outcome measure. Weaver¹⁶ reported that at least 6 h of PAP use per night was necessary to normalize functional outcomes associated with sleepiness in patients with OSA. Campos-Rodriguez and colleagues¹⁷ reported a relationship between at least 6 h of nightly PAP use and lower 5-year cumulative mortality rates. These studies have suggested that improvements in PAP therapy adherence may also be related to improvements in clinical outcome, thereby supporting a dose-response relationship.

The objective of the current study was to examine

the degree to which varying levels of PAP adherence normalized memory at a 3-month follow-up visit in memory-impaired patients with OSA. We were specifically interested in individuals who exhibited impairments in memory prior to receiving PAP treatment for several reasons. Memory difficulties are a common objectively measured cognitive impairment and subjective concern in patients with OSA.⁶ Although previous reports^{13,18–21} have examined memory improvement with PAP use, little attention has been given to improvement in individuals with impaired baseline memory. It is inherently difficult to detect treatment-associated cognitive gains in individuals who are performing in the average range or better prior to initiation of treatment. The identification and examination of patients who exhibit cognitive impairment prior to the initiation of treatment provides a unique opportunity to explore the efficacy of potential therapeutic interventions in a clinical population of individuals who may be more likely to experience meaningful beneficial results. We hypothesized that OSA patients exhibiting memory impairment at baseline with the greatest levels of PAP treatment adherence after 3 months would be more likely to demonstrate improvements in memory function compared to patients with relatively moderate or poor adherence to treatment.

MATERIALS AND METHODS

Participant Characteristics

One hundred seventy-nine participants in whom OSA had been diagnosed were recruited from the Sleep Disorders Center of Lifespan Hospitals of Rhode Island. All participants were naïve to PAP treatment. Fifty-eight of these participants (32%; men, 49

participants; white, 51 participants) exhibited memory impairments at a baseline assessment and were included in the current analyses. Eligibility for participation included the following: (1) age between 25 and 85 years; (2) diagnosis of OSA by polysomnography; (3) English language speaker; (4) no comorbid medical disorder; (5) no previous treatment with PAP; and (6) impaired memory function at baseline. All participants underwent a memory assessment at baseline and at a 3-month follow-up visit. Written informed consent was obtained from all participants. This study was approved by relevant institutional review boards.

Procedures and Measures

Cognitive Evaluation: Memory testing was performed by trained research assistants who were blind to apnea severity and not directly involved in participant treatment. The Hopkins verbal learning test-revised (HVLTR)²² was administered to assess memory function. Alternate forms of the HVLTR were used at each assessment to minimize test-retest effects. The HVLTR is a commonly used clinical measure with well-developed normative data, adequate construct and content validity,²³ and test-retest reliability for alternate forms.²² Standardized verbal memory scores (T scores) were calculated from published, age-matched normative data at each assessment. T scores are normally distributed with a mean of 50 and an SD of 10. Impairment of verbal memory performance was defined as a T score of at least 1 SD below the mean ($T \leq 40$) on delayed recall at the baseline assessment.^{24,25} Verbal memory abilities were determined to be normalized when a memory-impaired participant exhibited improvements in performance at a T score of ≥ 40 at the 3-month follow-up visit. The primary dependent variable of interest for analyses was the T score derived from the number of words recalled following a delay period.

The American New Adult Reading Test²⁶ was administered to obtain an estimated verbal intelligence quotient and to provide a measure of overall intellectual ability. The American New Adult Reading Test has been found to correlate highly with scores on standardized verbal intelligence measures.^{26–28}

Clinical Polysomnography: OSA was diagnosed using a full night of in-laboratory clinical polysomnography. Apneas and hypopneas were scored using American Academy of Sleep Medicine Task Force-recommended guidelines,²⁹ with hypopneas defined as 10 s of a 30 to 50% drop in nasal pressure airflow associated with a 4% drop in oxygen desaturation and/or American Sleep Disorders Association-defined arousal from sleep. Titration was conducted during a separate full-night polysomnography. The goal of the PAP titration was to determine the pressure required to reduce the apnea-hypopnea index (AHI) to fewer than five events per hour and to eliminate snoring. The majority of participants (85% [titration data were unavailable for four participants]) achieved an AHI of fewer than five events per hour on the night of titration. There were no PAP adherence group differences (see the “Adherence Categorization” subsection) on AHI on the night of titration ($F[2,53] = 1.55$; $p < 0.22$). Apnea severity measures included AHI and the percentage of total sleep time spent at $< 90\%$ blood oxygenation during the overnight polysomnography. Measurements of height, weight, and body mass index (in kilograms per square meter) were obtained.

Sleepiness: Subjective sleepiness was measured using the Epworth sleepiness scale.³⁰ This self-report scale requires participants to rate their likelihood of falling asleep under various circumstances on a scale of 0 (no chance) to 3 (high chance). Scores range from 0 to 24, with higher scores indicative of greater subjective daytime sleepiness. The clinical cutoff score for this scale is a score of ≥ 10 . This measure has been shown to have adequate reliability and validity.³⁰

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The work presented in this article was supported by National Institutes of Health grant R01 HL 67209 (to M.S.A.).

Drs. Aloia, Stanchina, and Millman have received funding from an unrestricted educational grant from Respiroics, Inc. Dr. Millman has also received funding for speaking engagements from Cephalon, Sanofi-Aventis, King Pharmaceutical, and Orphan Medical, and has served as a consultant for Cypress Bioscience. None of the authors has any conflicts of interest to report.

Manuscript received January 4, 2006; revision accepted May 24, 2006.

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DOI: 10.1378/chest.130.6.1772

PAP Adherence: All participants were prescribed the use of a PAP device (REMstar Pro CPAP or C-Flex; Respirationics; Murrysville, PA) that were set up and maintained through a single home health-care company. Heated humidification was supplied for each PAP device to minimize the impact of upper airway dryness on treatment adherence.³¹ Adherence was covertly monitored using internal microprocessors that were housed within the PAP devices. Adherence was reported as the total number of hours of PAP use at the prescribed pressure per 24-h period. Adherence data were collected at the 3-month follow-up visit and are presented in this study as the average nightly use over the 3-month period. An *a priori* decision was made not to inform participants that their PAP use was being monitored unless they asked for this information directly; however, this did not occur for any participants in this study.

Adherence Categorization: To examine the relative contribution of PAP adherence to the normalization of verbal memory performance, participants were placed into the following three groups based on average nightly PAP adherence: (1) poor users ($n = 14$), who used PAP an average of < 2 h per night; (2) moderate users ($n = 25$), who used PAP an average of 2 to 6 h per night; and (3) optimal users ($n = 19$), who used PAP an average of > 6 h per night. PAP adherence was examined as a categorical variable rather than a continuous variable because it was not normally distributed in either the larger screened sample or the subgroup of 58 participants with impaired verbal memory, making the use of linear statistical procedures inappropriate for analysis. Nonnormal distributions of adherence data are commonly observed in health-care populations and have been shown to be resistant to normalization procedures.³² The determination of our criteria for optimal users was based on two previous reports.^{16,17} In the first study, Weaver¹⁶ reported a relation between an average of 6 h of nightly PAP use and improvements in functional outcome. Campos-Rodriguez and colleagues¹⁷ also reported that 6 h of PAP use per night were associated with improvements in 5-year survival rates and cardiac morbidity compared to individuals who used PAP < 1 h per night. Poor users were defined as very minimal users of PAP and as the designated reference group for analyses. Following the placement of the appropriate participants in our sample into each of these two groups, the remaining participants were placed into a third group that were designated moderate users. This categorization process resulted in comparable group sample sizes.

Statistical Analysis

Data analyses were conducted using a statistical software package (SPSS, version 12.0; SPSS Inc; Chicago, IL). The data are presented as the means \pm SD, unless otherwise noted. Univariate analysis of variance was performed to determine where there were any group differences among demographic, cognitive, or other outcome variables. Tukey honestly significant difference follow-up tests were conducted to identify pairwise group differences when the omnibus test was statistically significant. A nonparametric Kruskal-Wallis test was conducted to verify group differences in PAP adherence.

To examine the normalization of memory abilities, binary logistic regression analysis was performed to identify the differential effect of categorized PAP adherence (*ie*, poor users, moderate users, and optimal users) on the prediction of verbal memory performance improving to the average range at 3 months in participants with verbal memory impairment prior to PAP therapy initiation. The dependent variable was normal verbal delayed recall memory performance at 3 months, the predictor variables were categorizations of PAP adherence, and the reference group was poor users. χ^2 analyses were performed

to examine adherence group differences between the number of people who normalized memory function or remained memory impaired at 3 months. Finally, to examine the specificity of findings to PAP use categorization, a nonparametric Kruskal-Wallis test was performed on 3 months of PAP use between memory-impaired and normal memory groups.

RESULTS

Sample Characteristics

Characteristics of the sample and of each adherence categorization of PAP users are shown in Table 1 along with memory performance scores. Analysis of variance revealed no significant group differences among the demographic variables. At baseline, the average verbal memory T score, the primary outcome variable, was approximately 2 SDs below the mean ($T = 30.1 \pm 7.3$) for all participants. At 3 months, the average verbal memory T score for the entire sample improved to approximately 1 SD below the mean ($T = 38.9 \pm 10.1$). Poor users had a mean (\pm SD) T score of 34.7 ± 10.2 , moderate users had a mean T score of 38.9 ± 10.4 , and optimal users had a mean T score of 42.0 ± 9.0 .

PAP Adherence

Adherence data are presented in Table 1. As a group, participants exhibited a median PAP use of 4.1 h per night (range, 0 to 8.4 h per night) at 3 months. As expected from the design of the study, a nonparametric Kruskal-Wallis test revealed a significant group difference in PAP adherence at 3 months ($\chi^2 = 49.64$; $p < 0.00001$), with optimal users exhibiting greater average nightly adherence (median use, 6.4 h per night; range, 6.1 to 8.4 h per night) than both poor users (median use, 0.9 h per night; range, 0 to 1.9 h per night) and moderate users (median use, 3.7 h per night; range, 2.3 to 5.9 h per night), with moderate users exhibiting greater adherence than poor users. Kruskal-Wallis tests revealed identical patterns of average adherence to treatment among the three groups after 1 week, 2 weeks, and 1 month of PAP use, indicating consistent patterns of use over the entire 3-month follow-up period.

Normalization of Verbal Memory

Two groups characterizing PAP adherence (moderate users and optimal users) were each compared to poor users using logistic regression in the prediction of normalized verbal delayed recall memory performance assessed at the 3-month follow-up visit. Statistically significant results indicated that the odds of optimal users exhibiting the normalization of

Table 3—PAP Adherence, OSA Severity, Age, and Education in the Prediction of Normalization of Verbal Memory Performance at 3 Mo*

Variables	B Statistic	Wald Statistic	p Value	OR	95% CI
Moderate users	1.95	3.73	0.05	7.06	0.97–51.23
Optimal users†	3.04	7.56	0.01	20.98	2.40–183.79
AHI	−0.01	0.13	0.72	1.00	0.96–1.03
Sa90	0.01	1.80	0.18	1.01	1.00–1.01
Age	−0.06	2.84	0.09	0.94	0.88–1.01
Education	0.16	1.59	0.21	1.18	0.92–1.51
Constant	−1.39	0.29	0.59	0.25	

*Logistic regression was performed with the reference group defined as poor users. See Table 1 for abbreviation not used in the text.

†Significant at the $p < 0.05$ level.

DISCUSSION

The findings from this preliminary study suggest that memory-impaired OSA participants who use PAP treatment an average of 6 h per night are nearly eight times as likely to demonstrate memory abilities in the clinically normal range after 3 months compared to individuals who used PAP for ≤ 2 h per night. Overall, 21% of poor users, 44% of moderate users, and 68% of optimal users demonstrated normal memory following 3 months of PAP treatment. Memory dysfunction is a common cognitive deficit and subjective concern in patients with OSA.⁶ Although it has been suggested that not all OSA-associated cognitive impairments are reversible with PAP treatment,^{13,33} improvements in memory function following varying periods of PAP use have consistently been reported in the literature.^{13,18–21} However, an important distinction that has received little attention in the literature is that a relative improvement in memory function in OSA patients does not necessarily indicate that OSA patients are performing “normally,” or at the same cognitive level as healthy control subjects. The pervasiveness of memory impairment and the reported positive response to treatment highlight the clinical relevance of an examination of normalization of memory function in the OSA patient. Our findings both contribute to and extend the current literature examining the relation between cognition and PAP adherence, and suggest that at least 6 h per night of PAP treatment may be required to produce a reversal of baseline memory impairment. Weaver¹⁶ reported a similar finding using a measure of functional outcome. Campos-Rodriguez and colleagues¹⁷ also reported that 6 h of PAP use per night were associated with improvements in 5-year survival rates using categorizations that were similar to those utilized in this study. The identification of a PAP use threshold is particularly important as relatively few OSA patients utilize this level of treatment.³⁴ Taken together, these findings highlight the importance of

the consideration of PAP adherence when the normalization of cognitive performance is a desired clinical outcome in patients with OSA.

An important construct that may contribute to baseline cognitive abilities in patients with OSA is cognitive reserve. Cognitive reserve is conceptualized as a protective factor that characterizes an individual’s relative ability to compensate for pathologic insults to the brain.^{35,36} In a recent study³⁷ examining cognitive reserve in patients with OSA, OSA patients of average intelligence demonstrated a decline in attentional function compared to control subjects of average intelligence at a baseline assessment, while OSA patients of above-average intelligence demonstrated no cognitive differences compared to control subjects of above-average intelligence. These differences were no longer evident following 1 year of PAP treatment, which led

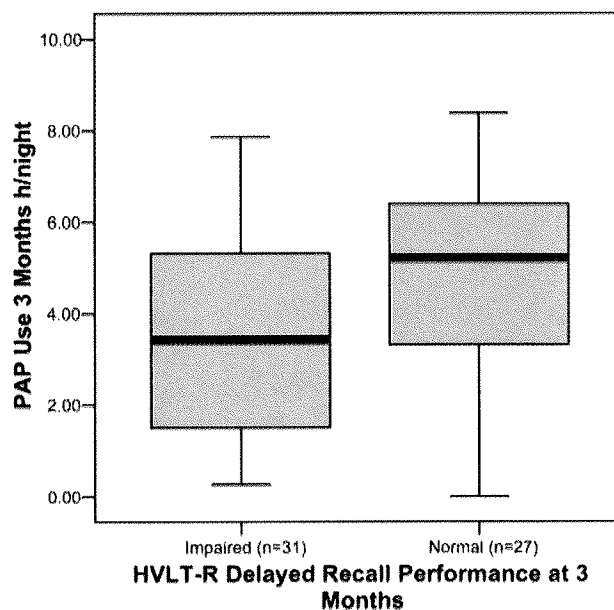


FIGURE 1. Adherence to PAP treatment after 3 months by HVL-R normalization group.

the authors to conclude that cognitive reserve, characterized as above-average intelligence, may have provided a protective effect against the cognitive decline associated with OSA prior to PAP treatment. In the current study, however, there were no differences in estimated intelligence at baseline, with participants exhibiting intelligence scores in the average range. It is not expected, therefore, that differences in baseline cognitive ability significantly contributed to the current findings. In future studies, however, consideration of the effect of differences in baseline cognitive abilities would be important for any interpretation of cognitive sequelae associated with OSA.

A limitation of the current study is the relatively small sample size. Only 32% of screened OSA patients met the criterion for baseline memory impairment. It is possible that the level of memory impairment required for consideration in the current analyses reflects a relatively small percentage of the overall population of OSA patients. Our sample size also precluded the examination of narrower PAP adherence categorizations. Future studies should consider additional adherence use cutoffs to further inform the clinical meaningfulness of the dose-response relationship between PAP use and improvements in memory. Our primary findings also revealed a large CI using logistic regression (95% CI, 1.60 to 39.42). Although large, even the low end of this interval suggests that optimal users are more likely to normalize their memory performance compared to poor users. Additional large-scale studies that examine the cognitive function of OSA patients prior to the initiation of treatment are needed to fully address this question. An additional limitation of this study is its primary focus on memory impairment. The critical threshold of 6 h per night of PAP treatment suggested by our findings may not apply to performance on tasks of other cognitive domains (*eg*, attention, vigilance, and executive functions). Future studies should evaluate the effects of varying levels of PAP adherence on a range of cognitive abilities, their interaction with each other, and their effect on additional functional outcomes. Finally, an important consideration in the interpretation of the results is the finding that although clinically significant improvements in memory abilities were demonstrated by many individuals who adhered to PAP use, there were also adherent individuals who did not demonstrate clinically meaningful improvements. This limitation highlights the complex nature of adherence outcomes in clinical samples and supports continued research efforts utilizing a broad examination of potentially critical contributing factors.

Overall, these preliminary findings indicate that impaired verbal memory performance in patients

with OSA may be reversible with optimal levels of PAP treatment. OSA patients exhibiting verbal memory deficits may experience a clinically meaningful benefit in their memory abilities when they use PAP at least 6 h per night. However, our findings also suggest that this level of PAP adherence is uncommon following 3 months of PAP treatment. Interventions to improve PAP adherence might utilize a 6-h threshold as a goal for optimal adherence where clinical outcomes are examined. Finally, the information obtained from these results could be used as a potential motivator for OSA patients struggling with poor PAP adherence.

ACKNOWLEDGMENT: The authors gratefully acknowledge Leisha Smith, Jaime Skrekas, Sarah Harris, and Charleen Pysz for assistance with patient recruitment, neuropsychological assessment, data entry, and manuscript preparation. We also thank the individuals who gave their time to take part in the study.

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Table 1—Demographic Characteristics and Adherence of the Sample*

Variables	Total (n = 58)	Poor Users (n = 14)	Moderate Users (n = 25)	Optimal Users (n = 19)	F Value	p Value
Age, yr	48.1 (10.1)	43.1 (11.9)	51.2 (6.7)	47.7 (11.4)	3.11	0.05
Education, yr	13.3 (2.8)	14.6 (2.5)	13.3 (3.0)	12.3 (2.5)	2.83	0.07
Male gender†	49 (84)	14 (100)	20 (80)	15 (79)	3.40	0.18
White race‡	51 (88)	12 (86)	23 (92)	16 (84)	6.20	0.40
Weight, lb	234.8 (43.7)	230.6 (35.6)	232.2 (49.1)	241.6 (42.8)	0.32	0.73
Body mass index, kg/m ²	34.6 (6.7)	32.2 (6.2)	35.1 (6.6)	35.8 (6.9)	1.33	0.27
Sa90, %	27.7 (33.9)	31.7 (37.6)	29.0 (33.1)	23.1 (33.8)	0.26	0.78
AHI, events/h	46.1 (27.9)	52.0 (29.1)	43.3 (29.7)	45.1 (25.5)	0.41	0.67
Estimated verbal IQ	107.9 (10.2)	111.5 (9.3)	106.4 (11.4)	107.6 (9.1)	1.09	0.34
ESS, total score/24 h	11.6 (4.9)	11.1 (5.5)	12.6 (5.0)	10.5 (4.4)	1.00	0.38
3 mo PAP use,‡ h/night	4.1 (0–8.4)	0.9 (0–1.9)	3.7 (2.3–5.9)	6.4 (6.1–8.4)	49.64	0.00§
Baseline memory T score	30.1 (7.3)	30.2 (6.5)	29.0 (8.1)	31.4 (6.8)	0.55	0.58

*Values are given as the mean (SD), unless otherwise indicated. Sa90 = Total sleep time spent below 90% blood oxygenation; IQ = intelligence quotient; ESS = Epworth sleepiness scale.

†Values are given as the total No. (%).

‡Values are given as the median (range).

§Statistically significant at the $p < 0.01$ level.

delayed recall memory following 3 months of PAP use was 7.9 times ($p = 0.01$; 95% confidence interval [CI], 1.60 to 39.42) the odds of poor users exhibiting the normalization of delayed recall memory. The results were not statistically significant for moderate users of PAP; the odds of this group demonstrating memory normalization after 3 months were 2.8 times ($p = 0.17$; 95% CI, 0.64 to 12.93) the odds of poor users demonstrating memory normalization after 3 months. χ^2 analysis for the linear association was statistically significant ($\chi^2 = 7.59$; $p < 0.03$), indicating that an increase in adherence, defined by our groupings, was associated with a similar increase in the normalization of memory abilities. Table 2 displays statistics and odds ratios (ORs) for each of the predictors. χ^2 analysis revealed statistically significant PAP use group differences in the normalization of memory abilities ($\chi^2 = 7.27$; $p = 0.03$), with 21% of poor users, 44% of moderate users, and 68% of optimal users demonstrating normal memory performance at 3 months.

To examine the contribution of OSA severity, age, and education to the relation between PAP adher-

ence and memory improvement, we repeated logistic regression analyses with AHI, time spent below 90% of arterial oxygen saturation, age, and education as additional predictor variables. The latter two demographic variables were included in the model because PAP adherence group differences on these variables approached statistical significance (Table 1). The results were essentially unchanged, with optimal users remaining as a significant predictor of normalization of delayed recall memory function following 3 months of PAP use (OR, 20.98; 95% CI, 2.40 to 183.79; $p = 0.01$). Table 3 displays statistics and ORs for each of the predictors. We also examined the relation between baseline verbal memory performance and PAP adherence in the prediction of memory performance at 3 months. We repeated logistic regression analyses with the inclusion of the interaction between baseline memory performance and PAP adherence group as an independent variable to predict memory normalization at 3 months. None of the interactions between baseline memory performance and PAP adherence group reached statistical significance ($p = 0.29$ to 0.36), suggesting that our PAP adherence finding was not moderated by baseline performance on the verbal memory task.

Finally, when the entire sample was divided into participants who demonstrated normalized memory and participants who remained memory-impaired at 3 months, a Kruskal-Wallis test revealed a significant group difference in average nightly PAP use ($\chi^2 = 5.43$; $p = 0.02$). Participants who exhibited normal memory performance at 3 months had used PAP more often than those who remained memory-impaired (median use, 5.21 vs 3.42 h per night) [Fig 1].

Table 2—PAP Adherence in the Prediction of Normalization of Verbal Memory Performance at 3 Mo*

Variables	B Statistic	Wald Statistic	p Value	OR	95% CI
Moderate users	1.10	1.90	0.17	2.88	0.64–12.93
Optimal users†	2.07	6.43	0.01	7.94	1.60–39.42
Constant	-1.30	3.98	0.05	0.27	

*Logistic regression was performed with the reference group defined as poor users.

†Significant at the $p < 0.05$ level.

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Chest 2006;130; 1772-1778
DOI 10.1378/chest.130.6.1772

This information is current as of January 4, 2010

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A M E R I C A N C O L L E G E O F



P H Y S I C I A N S[®]

Normalization of Memory Performance and Positive Airway Pressure Adherence in Memory-Impaired Patients With Obstructive Sleep Apnea*

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Abstract

Background: Although the treatment of obstructive sleep apnea (OSA) with positive airway pressure (PAP) has been shown to be effective, nightly adherence to treatment remains poor. The objective of this study was to examine the degree to which various levels of PAP therapy adherence normalized verbal memory function after 3 months of therapy in patients with OSA who were memory-impaired prior to the initiation of PAP therapy.

Methods: Participants were administered neuropsychological testing prior to the initiation of PAP treatment and at a 3-month follow-up visit. Fifty-eight memory-impaired participants were categorized into the following three groups based on 3 months of adherence to PAP therapy: (1) poor users (n = 14), participants who averaged < 2 h of PAP use per night; (2) moderate users (n = 25), participants who averaged 2 to 6 h of PAP use per night; and (3) optimal users (n = 19), participants who averaged > 6 h of PAP use per night.

Results: Logistic regression analyses revealed that the odds of optimal users exhibiting normalization of memory function following 3 months of PAP therapy were 7.9 times (p = 0.01) the odds of poor users exhibiting normalization of memory abilities. Overall, 21% of poor users, 44% of moderate users, and 68% of optimal users exhibited memory performance in the clinically normal range following 3 months of PAP use ($\chi^2 = 7.27$; p = 0.03).

Conclusions: These preliminary findings indicate that impaired verbal memory performance in patients with OSA may be reversible with optimal levels of PAP treatment. OSA patients exhibiting verbal memory impairments may experience a clinically meaningful benefit in their memory abilities when they use PAP for at least 6 h per night.

adherence cognition compliance memory obstructive sleep apnea positive airway pressure

Footnotes

Abbreviations: AHI = apnea-hypopnea index; CI = confidence interval; HVLt-R = Hopkins verbal learning test-revised; OR = odds ratio; OSA = obstructive sleep apnea; PAP = positive airway pressure

The work presented in this article was supported by National Institutes of Health grant R01 HL 67209 (to M.S.A.).

Drs. Aloia, Stanchina, and Millman have received funding from an unrestricted educational grant from Respiroics, Inc. Dr. Millman has also received funding for speaking engagements from Cephalon, Sanofi-Aventis, King Pharmaceutical, and Orphan Medical, and has served as a consultant for Cypress Bioscience. None of the authors has any conflicts of interest to report.

Accepted May 24, 2006.
Received January 4, 2006.

Articles citing this article

N. S. Freedman

Positive Airway Pressure Therapy for Obstructive Sleep Apnea Syndrome: The Boards and Beyond
ACCP Sleep Med Brd Rev January 1, 2009 4:293-312;

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