

MEDICAL EDUCATION SYSTEMS, Inc.

103
CPAP- Titration



Medical Education Systems, Inc

TOLL FREE: 877-295-4719

LOCAL: 619-295-0284

FAX: 619-295-0252

EMAIL: info@mededsys.com

WEBSITE: www.mededsys.com

P.O Box 81831 San Diego, CA 92138-3939.

Daytime CPAP Titration*

A Viable Alternative for Patients With Severe Obstructive Sleep Apnea

Learning Objectives

Upon successful completion of this course, you will be able to:

- Define what is meant by Daytime CPAP Titration
- Compare results of patients who receive a regular nocturnal CPAP titration with patients who receive a daytime CPAP titration.
- Explain the purpose of daytime CPAP titration

Introduction

What is a CPAP titration study, and why did my doctor order this test?

CPAP stands for continuous positive airway pressure. Nasal CPAP therapy is a non-invasive, non-surgical way to treat obstructive sleep apnea.

When a patient comes into the Sleep Center to be titrated on nasal CPAP, he or she is fitted with a relatively small, comfortable mask that goes over the nose only. This mask is hooked up to a CPAP unit, which delivers an air pressure through the nose into the back of the airway to splint the airway open during sleep with air. Initially, the CPAP unit uses a low air pressure that allows patients to breathe easily in and out against the slight pressure. When the patient is asleep, the pressure is adjusted (titrated) to keep the back of the airway open during sleep. Pressure is titrated to keep the patient apnea-free in all stages of sleep and in all body positions. The CPAP allows the patient to achieve restful and deep sleep without interruption during the night. Patients with sleep apnea not only get a good night's sleep on CPAP therapy, but also prevent long-term damage to their heart and body that could be caused by lack of oxygen and poor sleep.

Course Objective: Continuous positive airway pressure (CPAP) is the treatment of choice for patients diagnosed with severe obstructive sleep apnea (OSA). The implementation of CPAP therapy has traditionally been based on full-night titration studies or split-night protocols. This study compared a group of patients who received a regular nocturnal CPAP titration with patients who received a daytime CPAP titration. The objective of the study was to determine if daytime CPAP titration is a viable alternative for the implementation of CPAP treatment in patients with severe OSA.

Study design: Fourteen patients (13 men and one woman) received a daytime CPAP titration (day group). The day group was matched to 18 patients (17 men and one woman) who were titrated under a full-night regular nocturnal study (night group). Eligible patients were those with severe OSA (respiratory event index > 40). The groups were matched by age, sex, and body mass index.

Results: Daytime and nocturnal CPAP titration studies yielded sufficient amounts of rapid eye movement (REM) and non-REM sleep to help determine CPAP settings. Importantly, the diurnal and nocturnal CPAP titrations resulted in comparable therapeutic pressures as well as comparable

resolution of sleep-disordered breathing. After 1 week of treatment, the groups exhibited similar CPAP use and comparable improvements in subjective sleepiness as indicated by their increase in sleep/wake activity inventory scores.

Conclusions: Daytime CPAP titration studies may be a viable alternative for the efficient and expedient implementation of CPAP therapy among some patients with severe OSA.

Key words: acceptance; compliance; continuous positive airway pressure; excessive daytime sleepiness; obstructive sleep apnea; split-night protocol; treatment

Abbreviations:

ANOVA⁵analysis of variance;
CPAP⁵continuous positive airway pressure;
CPSG⁵clinical polysomnography;
NREM⁵nonrapid eye movement;
OSA⁵obstructive sleep apnea;
REI⁵respiratory event index;
REM⁵rapideye movement;
Sao²⁵arterial oxygen saturation;
SWAI⁵sleep/wake activity inventory;
TIB⁵time in bed

The use of continuous positive airway pressure (CPAP) as a therapeutic option in patients with obstructive sleep apnea (OSA) is recognized as safe and efficacious. However, there is yet no consensus about what constitutes the most effective and cost-efficient CPAP titration protocol. The American Thoracic Society's consensus statement in this regard recognizes the need to include various body positions as well as nonrapid eye movement (NREM) and rapid eye movement (REM) sleep in order to determine the optimal CPAP pressure.¹ The guidelines, however, do not make specific suggestions as to the timing or duration of CPAP titration studies.

In an effort to expedite treatment, maximize resource utilization, and contain costs, many sleep centers have adopted split-night polysomnographic studies for the diagnosis and treatment of this patient population. Studies utilizing this protocol have demonstrated that a majority of patients with OSA can be diagnosed and titrated on the same night in the laboratory.^{2–6} However, it is clear from the available studies that some patients may require additional adjustments after the split-night protocol.^{5,6}

The split-night protocol has raised a number of clinical concerns as well. It may potentially interfere with the natural course of the physician-patient interaction. This protocol requires the physician to communicate to the patient the need for a diagnostic test and to express the rationale of the diagnosis, its severity, and the need for therapeutic intervention within the constraints of the first consultation. This is a difficult task considering that OSA is a chronic condition, particularly because a substantial number of patients only attend the consultation upon their spouse's insistence. Clinical experience suggests that patients are more receptive to discussing treatment alternatives following a diagnostic test. It has, therefore, become desirable to have alternative therapeutic paradigms that enable prompt implementation of CPAP therapy once the diagnosis is made.^{7,8} Thus, the purpose of this study was to determine if the use of a daytime CPAP titration in patients with severe OSA, after diagnostic nocturnal clinical polysomnography (CPSG) has been performed, is a viable alternative for the implementation of CPAP treatment.

Materials and Methods

Data were gathered from a total of 32 patients with severe OSA (30 men, two women). Severe OSA was defined as a respiratory event index (REI) of ≥ 40 (with $\geq 80\%$ of the events being obstructive or mixed), associated with significant arterial oxygen desaturations (index of O_2 desaturations below 85% was ≥ 15). Eligible patients were those with nocturnal sleep schedules in whom, based upon a physician's (LR or PG) clinical impression and review of the CPSG (the morning after the study), a daytime CPAP titration was justified so as to initiate treatment without further delay (13 men, one woman). The daytime patients were matched, by sex, age, body mass index, and REI, to 18 patients (17 men, one woman) who completed a nighttime CPAP titration following our clinic's regular protocol. All studies were performed from January through August 1996.

All patients completed an initial questionnaire to assess their symptoms and sleep/wake characteristics (including a shortened version of the sleep/wake activity inventory or SWAI).⁹ The patients were clinically evaluated by a physician board-certified in sleep disorders medicine. For CPSG, patients were required to refrain from caffeine and or alcohol use for at least 5 h prior to arrival at the laboratory. The patients were instructed to continue all of their prescribed medications. Patients were asked to be at the laboratory 2 h before their habitual bedtime. Patients had electrodes hooked up by trained technicians. Electrode placements included unipolar monitoring of the central and occipital EEGs, electro-oculograms, and submental electromyogram. An ECG, tibialis anterior electromyogram to monitor for periodic leg movements, a position monitor, and a snoring microphone were also used. Respiration was monitored with a thermistor at the nose and mouth to detect airflow and by a thoracoabdominal strain belt to detect respiratory effort (EPM Resp-Ez; EPM Systems; Midlothian, VA). Oximetry was recorded using a finger oximeter (Biox 3700; Ohmeda; Louisville, CO) worn on the patient's first or second digit. Subjects were kept in bed for 8 h during all nocturnal recordings. However, in a few instances patients requested a shortened time in bed. Among the latter patients, no one underwent recording for a period shorter than 6 h.

Prospective patients for daytime testing were identified by their treating physician within an hour or two after the patient's rising time. This decision was based on the severity of their condition, derived from both the clinical evaluation and the morning review of the CPSG. Patients were required to follow a nocturnal sleep schedule and have manifestations of severe OSA. Clinically, patients were required to complain of severe snoring and excessive daytime sleepiness. The polysomnographic criteria are defined above. The physician met with the patients the morning after CPSG to review their results and to discuss the need for CPAP titration. Those patients who were unable to stay for daytime CPAP titration (or left before the physician reviewed their CPSG) followed the regular sleep apnea protocol. Patients received an abbreviated CPAP education session that emphasized mask fitting. If needed, patients took their medications following the education session. Patients then ate breakfast and were prepared for their daytime CPAP titration study.

Those patients who followed the regular sleep apnea protocol returned for an office visit (sometimes as soon as the day following the diagnostic CPSG). During the office visit, the patient's physician reviewed the results of the evaluation and discussed treatment alternatives. For severe cases, CPAP was always recommended as an initial form of therapy. A CPAP education session by a specialized technician immediately followed the consultation. During the CPAP education session, patients were given a brief explanation of the proper use of the CPAP machine, were fitted with a mask, and were allowed to experience CPAP while sitting in a comfortable recliner for 10 to 15 min. Patients were then scheduled for a nocturnal CPAP titration.

A consistent effort at offering daytime titration to all patients with severe OSA was made from January through August 1996. However, as stated above, some patients were unable to stay for a daytime titration, while others left the laboratory before the appropriate physician was able to review their polysomnogram. Thus, group assignment was fortuitous. During the time of data collection, 14 patients with severe OSA completed the daytime protocol. These patients were matched to 18 patients with comparable age and OSA severity who completed the nocturnal CPAP titration protocol.

The same CPSG variables recorded during the diagnostic study were monitored during the CPAP titration studies. The patients initiated their CPAP titration study wearing the mask determined to provide the best fit during the CPAP education session. CPAP trials were initiated at 5 cm H₂O with upward titration made in increments of 1 cm H₂O to eliminate apnea, hypopnea, and arousals associated with abnormal breathing events, including snoring. The increments were done at intervals of about 10 min.

Patients not spontaneously sleeping in the supine position were asked to turn over to the supine position once the CPAP setting was within a therapeutic range. Nocturnal and daytime titrations were done by different technicians. The nocturnal CPAP titration studies consisted of an 8-h CPSG, while daytime CPAP titration studies were at least 5 h long. Daytime titrations were shorter because of staffing limitations. Upon termination of CPAP studies, the treating physician determined the CPAP pressure required for optimum treatment of sleep-disordered breathing.

Upon termination of daytime titration, patients completed a CPAP education session focusing on the operation of the equipment. All patients were furnished with a CPAP unit set at their prescribed pressure for 7 to 10 days. These units contained a covert microprocessor to determine their nightly use. The microprocessor monitored the number of hours in which the therapeutic pressure was delivered to the patients each night. It was explained to the patients that the equipment they would be using enabled their physician to monitor their nightly CPAP use. Upon their return to the laboratory for a follow-up clinic visit, the patients were asked to complete a brief questionnaire to determine their symptoms, acceptance and use of CPAP, and levels of sleepiness (as determined by a shortened version of the SWAI). The nightly use of CPAP was also determined from the CPAP unit.

Each CPSG was scored manually in 30-s segments.¹⁰ An interrater reliability of 90% or better was maintained throughout the study. Hypopneas were defined as a $\geq 50\%$ reduction of nasal/oral airflow for at least 10 s. Apneas were scored according to commonly used criteria for airflow cessation of ≥ 10 s. An REI, defined as the sum of the hypopnea index and apnea index, was calculated for each patient.

The data were analyzed using SPSS 6.1 for Macintosh (SPSS Inc; Chicago, IL). Independent *t* tests were used for the statistical comparisons between the two groups. Variables were submitted to a one-way analysis of variance (ANOVA) with the timing of CPAP titration (day or night) as the independent variable. Where indicated, repeated-measures analyses were performed with diagnostic and titration CPSG parameters as the repeated measures. Tukey's post-hoc comparisons were utilized where appropriate.

Results

Both patient groups were comparable and fairly representative of patients with severe OSA (Table 1). There were no significant differences in the REI or the index of times when the Sao₂ dropped below

85%. However, the index of the number of minutes patients spent with an Sao2 below 85% was significantly higher (p , 0.05) for the day group when compared with the night group. The two groups had comparable levels of daytime sleepiness prior to treatment, as determined by the sleepiness scale of the SWAI. Furthermore, the CPAP pressures required for the normalization of breathing during sleep and the calculated REIs at these pressures were comparable for both groups (Table 1).

The patients’ sleep parameters were submitted to a one-way, repeated-measures ANOVA with the day and night groups as between-subject levels and the diagnostic and titration parameters as repeated measures (CPSG study). Time in bed (TIB) was comparable between the two groups on the diagnostic night. However, TIB was significantly shorter during the daytime CPAP titration (Table 2). Importantly, sleep efficiency was comparable during diagnostic and titration CPSG for both groups. Latency to stage 1 NREM sleep was comparable for both groups on the diagnostic studies, but was significantly shorter during the daytime titration (Table 2). A similar interaction was documented for latency to REM stage sleep; a shortened REM latency was demonstrated during the daytime CPAP titration when compared with the nocturnal CPAP titration (Table 2).

A significant main effect of CPSG study was documented for stage 1 NREM sleep time with significantly less stage 1 NREM sleep during the titration studies for both groups (Table 2). Time spent in stage 2 sleep during diagnostic and titration studies was comparable for both groups. Patients who underwent daytime CPAP titration demonstrated a significant increase in stage 3/4 sleep from their diagnostic CPSG. However, the night group demonstrated comparable levels of stage 3/4 sleep during both diagnostic and titration studies. The day and night groups documented significantly more REM sleep during their titration studies than during their diagnostic studies (Table 2). Relevant to the viability of the daytime CPAP titration is the amount of time patients in the day group spent asleep and the amount of REM sleep these patients accrued at their therapeutic CPAP pressures. Patients in the daytime titration group slept for a mean of 192 6 76 min at their therapeutic CPAP settings (*i.e.*, the prescribed pressure 6 1 cm H2O). This amount of sleep was comparable to the 211 6 111 min recorded at therapeutic CPAP settings for the nocturnal CPAP titration group. REM sleep accrual at the therapeutic CPAP settings was also comparable for the two groups. A total of 51 6 39 and 44 6 37 min of REM sleep was accrued for the daytime and nocturnal CPAP titration groups, respectively.

Table 1—Patient Characteristics*

	Day Group	Night Group	p Value
Age, yrs	41 ± 14	46 ± 15	NS
Body mass index	40 ± 8	38 ± 8	NS
REI	93 ± 54	84 ± 31	NS
Index of times SaO ₂ ≤85%	43 ± 35	35 ± 28	NS
Index of min SaO ₂ ≤85%	26 ± 25	12 ± 11	<0.05†
Excessive daytime sleepiness SWAI (initial)	37 ± 6	41 ± 12	NS
CPAP pressure	12 ± 2	12 ± 3	NS
Treated REI	6 ± 7	10 ± 7	NS
*Data presented as mean ± SD. NS = not significant			
†t test = 2.22			

Patients returned for a follow-up visit with their physician 1 week after the initiation of CPAP therapy.

At that time, their weekly compliance was downloaded from the microprocessor located in their CPAP unit. Two patients in the day group and three patients in the night group did not use their CPAP machines for the entire week and they were excluded from the compliance analysis. The number of nights in which patients in this study possessed their CPAP was 8 6 2 nights (day, 7 6 1 nights; night, 8 6 2 nights). Patients in the day group used their machines an average of 7 nights (range; 5 to 8 nights) for an average of 4.6 h (range; 1.0 to 7.0 h; median; 5.2 h) each night. Patients in the night group used their machines an average of 6 nights (range; 1 to 8 nights) for an average of 4.3 h (range; 1.0 to 8.3 h; median; 3.7 h) each night. There was not a difference between the groups in the length of possession, the number of nights patients used their CPAP machines, or the average nightly use. Patients also filled out the SWAI questionnaire at follow-up, and the groups demonstrated similar levels of subjective sleepiness (day, 60 6 18; night, 58 6 11) after treatment. A one-way, repeated-measures ANOVA with initial and follow-up SWAI scores (CPAP treatment) as repeated measures confirmed the groups to be comparable (Group, $F = 5.06$; $p =$ not significant). More importantly, however, a significant main effect of CPAP treatment ($F = 57.84$; $P = 0.001$) on SWAI scores indicated that both groups experienced a significant improvement in subjective daytime sleepiness after 1 week of treatment (day improvement, 23 6 12; night improvement, 17 6 10). There was not a group-by-CPSG-study interaction ($F = 4.28$; $p =$ not significant) for SWAI scores.

Discussion

The results of this study demonstrate that daytime CPAP titration may be a viable alternative for some patients with severe OSA syndrome. While the inclusion criteria required patients to have regular nocturnal sleep schedules, manifestations of severe OSA, and polysomnographic corroboration of severe OSA, further research will be required to accurately determine the ideal patient profile of those most likely to benefit from daytime CPAP titration studies. In this study, daytime CPAP titration after a diagnostic CPSG evaluation provided full documentation of the severity of the patient’s condition and at the same time enabled the physician to discuss the results of the study without delaying the initiation of treatment. From the laboratory point of view, this strategy facilitated the use of resources and shortened the waiting time for patients with severe OSA.

The sleep characteristics of daytime CPAP titration also serve to illustrate the homeostatic nature of sleep. It would seem unlikely that after spending 8 h in bed, patients would be able to tolerate returning to bed for an additional sleep period. Patients in this study did not manifest any difficulties with this strategy, however. Furthermore, the nature of their sleep clearly demonstrated improvements in their quality of sleep. From the perspective of CPAP titration, the daytime studies resulted in comparable amounts of REM sleep, which is critical to deriving the therapeutic CPAP pressures for treatment of this condition. It is of interest that the CPAP pressures derived from the nocturnal and daytime CPAP titration studies were comparable, particularly considering that the nocturnal and daytime CPAP titration studies were done by independent teams of technicians. These results are consistent with the comparable levels of severity that were documented during the diagnostic CPSG studies.

Table 2—Polysomnographic Characteristics During Diagnostic and Titration Studies*

	Day Group		Night Group	
	Diagnostic	Titration	Diagnostic	Titration
TIB, min	487 ± 39†	386 ± 49	467 ± 72	488 ± 27
Sleep efficiency, %	78 ± 11	85 ± 11	81 ± 10	80 ± 17
Latency to stage 1, min	7.9 ± 5.6†	3.0 ± 4.2	8.0 ± 4.7	10.1 ± 8.1
Latency to REM, min	122 ± 68†	33 ± 23	89 ± 50	64 ± 28
Stage 1, min	176 ± 84	53 ± 22	166 ± 101	72 ± 43

Stage 2, min	152 ± 84	148 ± 49	170 ± 76	218 ± 47
Stage 3/4, min§	4 ± 8‡	33 ± 30	15 ± 38	12 ± 16
REM stage, min§	34 ± 19	92 ± 39	34 ± 19	82 ± 39
*Data presented as mean ± SD.		‡p <0.05 vs titration.		
‡Main effect of group, p <0.05.		§Main effect of CPSG study, p <0.05.		
Interaction, p <0.05.				

Perhaps the most relevant issue concerning the viability of daytime CPAP titration is the outcome reported by the patients after 1 week of treatment. The two groups experienced comparable resolution of daytime sleepiness. In addition, their compliance with CPAP was comparable and consistent with our clinical experience of CPAP use during the first week of treatment.¹¹ Furthermore, this level of compliance is consistent with the compliance rates reported in the literature.^{12–15} However, it must be acknowledged that the assessment of long-term outcome measures would be highly desirable. We are currently making every effort to reach these patients in order to reevaluate their clinical status, CPAP compliance, and need for further titration.

There are limitations to this study that need to be acknowledged. Patients were not randomly assigned to the daytime or nocturnal titration groups. The study was, rather, the result of clinical necessity when physicians felt that a CPAP titration should not be delayed. During the data collection period, every effort was made to offer daytime titration studies to all eligible patients. Many of the patients, however, had already left the laboratory before the physician was available to review and discuss the results of the test. On many other occasions, the patients could not make the necessary arrangements to stay for the day.

These patients ended up forming the nocturnal CPAP group. While this group allocation may have resulted in a biased treatment assignment, the severity of the patients' conditions and demographic characteristics suggest that both groups are comparable. In terms of the methodology of the study, it is always undesirable to derive conclusions based on accepting the null hypothesis. However, the outcome variables, such as average CPAP use per night and patients' improvement in the level of daytime sleepiness, suggest that a daytime CPAP titration for some severe OSA cases may be a viable protocol for implementation of CPAP. Furthermore, the small differences between the two groups in this study strongly suggest that a very large sample size would be needed to reject the null hypothesis. Such a large sample size would make a study of this nature impractical, and would be of questionable clinical relevance.

The positive results derived from daytime CPAP titration studies has enabled us to incorporate this methodology into our clinical practice. We have found that patients accept this methodology and experience comparable outcomes when compared with patients titrated using the regular nocturnal protocol. However, caution should be exercised as for whom this strategy is a viable therapeutic protocol. Patients with milder degrees of sleep-disordered breathing are unlikely to tolerate this procedure. Thus, excessive utilization of daytime CPAP titration may potentially result in an increased percentage of CPAP failures. Patients with milder degrees of apnea should always be titrated during their regular sleep period.

References

- 1 American Thoracic Society. Indication and standards for use of nasal continuous positive airway pressure (CPAP) in sleep apnea syndromes. *Am J Respir Crit Care Med* 1994; 105: 1738–1745
- 2 Iber C, O'Brien C, Schluter J, et al. Single night studies in obstructive sleep apnea. *Sleep* 1991; 14:383–385
- 3 Strollo PJ, Sanders MH, Costantino JP, et al. Split-night studies for the diagnosis and treatment of sleep-disordered breathing. *Sleep* 1996; 19:S255–S259
- 4 Yamashiro Y, Kryger MH. CPAP titration for sleep apnea using a split-night protocol. *Chest* 1995; 107:62–66
- 5 Sanders MH, Kern NB, Costantino JP, et al. Adequacy of prescribing positive airway pressure therapy by mask for sleep apnea on the basis of a partial-night trial. *Am Rev Respir Dis* 1993; 147:1169–1174
- 6 Fleury B, Rakatonanahary D, Tehindrazanarivelo AD, et al. Long-term compliance to continuous positive airway pressure therapy (nCPAP) set up during a split-night polysomnography. *Sleep* 1994; 17:512–515
- 7 Juhasz J, Schillen J, Urbigkeit A, et al. Unattended continuous positive airway pressure titration: clinical relevance and cardiorespiratory hazards of the method. *Am J Respir Crit Care Med* 1996; 154:359–365
- 8 Lloberes P, Ballester E, Maria J, et al. Comparison of manual and automatic CPAP titration in patients with sleep apnea/ hypopnea syndrome. *Am J Respir Crit Care Med* 1996; 154:1755–1758
- 9 Rosenthal L, Roehrs T, Roth T. The sleep-wake activity inventory: a self-report measure of daytime sleepiness. *Biol Psychiatry* 1993; 34:810–820
- 10 Rechtschaffen A, Kales A. A manual of standardized terminology, techniques, and scoring systems for sleep stages of human subjects. Washington, DC: Public Health Service, US Government Printing Office, 1968
- 11 Rosenthal L, Nykamp K, Syron ML, et al. Compliance with CPAP during the first week of treatment. *Sleep Res* 1997; 26:489
- 12 Reeves-Hoche MK, Meck R, Zwillich W. Nasal CPAP: an objective evaluation of patient compliance. *Am J Respir Crit Care Med* 1994; 149:149–154
- 13 Engleman HM, Martin SE, Douglas NJ. Compliance with CPAP therapy in patients with the sleep apnoea/hypopnoea syndrome. *Thorax* 1994; 49:263–266
- 14 Kribbs NB, Pack AI, Kline LR, et al. Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea. *Am Rev Respir Dis* 1993; 147:887–895
- 15 Waldhorn RE, Herrick TW, Nguyen MC, et al. Long-term compliance with nasal continuous positive airway pressure therapy of obstructive sleep apnea. *Chest* 1990; 97:33–38 **1060** *Clinical Investigations Chest* 1998; 114:1056-1060 L Rosenthal, K Nykamp, P Guido, ML Syron, R Day, M Rice and T Roth obstructive sleep apnea

Can Patients with Obstructive Sleep Apnea Titrate Their Own Continuous Positive Airway Pressure?

Michael F. Fitzpatrick, Christi E. D. Alloway, Tracy M. Wakeford, Alistair W. MacLean, Peter W. Munt, and Andrew G. Day Departments of Medicine and Psychology, Queen's University, Kingston, Ontario, Canada

Abstract

Manual continuous positive airway pressure (CPAP) titration in a sleep laboratory is costly and limits access for diagnostic studies. Many factors affect CPAP compliance, but education and support, rather

than in-laboratory CPAP titration, appear to be pivotal. Self-adjustment of CPAP at home will provide equal or superior efficacy in the treatment of obstructive sleep apnea (OSA) as compared with in-laboratory titration. A randomized, single-blind, two-period crossover trial of CPAP treatment at the in-laboratory–determined optimal pressure versus at-home self-adjustment of CPAP (starting pressure based on prediction equation). Eighteen CPAP-naïve patients (16 males, 50 ± 15 years old, apnea hypopnea index 40 ± 20) with a new diagnosis of OSA were tested. Testing was performed before and after CPAP treatment in each of two 5-week study limbs. CPAP, compliance with CPAP treatment, the Sleep Apnea Quality of Life Index, the Functional Outcomes of Sleep Questionnaire score, the Epworth sleepiness scale score, sleep architecture, sleep apnea severity, and maintenance of wakefulness tests were performed. Both modes of CPAP treatment significantly improved objective and subjective measures of OSA, but they did not differ in efficacy. Home self-titration of CPAP is as effective as in-laboratory manual titration in the management of patients with OSA.

Obstructive sleep apnea (OSA) is a common condition, affecting 4% adult males and 2% adult females (1). It is associated with significant mortality and morbidity, and untreated OSA imposes a substantial healthcare burden on the economy (2). Since its original description in 1981 (3), continuous positive airway pressure (CPAP) has become the standard treatment for OSA. It is a particularly effective treatment for patients with moderate or severe OSA (4) but also has demonstrable benefits in patients with mild OSA (5, 6). CPAP titration to discern the optimal pressure required to alleviate upper airway obstruction during sleep usually includes a simultaneous recording of sleep, respiration, and oxygen saturation (7) and is typically conducted in a sleep laboratory. This practice is expensive (two overnight sleep laboratory studies per patient with OSA—diagnostic and CPAP titration) and limits access to the sleep laboratory for diagnostic studies. Recent evidence suggests that the use of automated CPAP devices (8) and abbreviated CPAP titrations (9) can improve the efficiency with which CPAP treatment is delivered, as compared with conventional in-laboratory overnight CPAP titration. Given the high disease prevalence and limited healthcare resources, carefully evaluated attempts at greater efficiency in managing patients with OSA are needed. Approximately 15% of patients with OSA refuse CPAP treatment at the outset (10, 11), and compliance among those who accept this treatment is frequently suboptimal (12, 13). More intensive education and support have been documented to improve clinical outcomes in patients with OSA (14), and provision of an abbreviated care regimen resulted in an inferior clinical outcome (15). It is therefore essential to document both compliance with treatment and clinical outcomes in association with any intervention aimed at improving the efficiency with which treatment is delivered to patients with OSA.

An educational model in which the patient is empowered with the understanding and ability to make decisions regarding treatment has been demonstrated to be successful in other medical conditions (16). We reasoned that a similar educational approach might be successful in patients with OSA who require CPAP treatment.

Although the level of educational support, disease severity, treatment response, and other factors have been identified as contributors to CPAP compliance (17, 18), each has accounted for only a small part of the variance in compliance among individuals. The latter fact and the unpredictability of CPAP compliance among patients with OSA have led to the belief that the individual patient's outlook on CPAP treatment may be of paramount importance in determining CPAP compliance (17, 19), which may seem intuitively obvious, given the somewhat cumbersome nature of the device.

We therefore designed an intraindividual crossover trial to compare outcomes between the conventional in-laboratory method of CPAP titration and patient self-titration of CPAP for OSA.

METHODS

Design

A randomized, single-blind, two-period crossover design was employed, with a 1-week wash-in period off CPAP, two 5-week treatment limbs, and a 1-week washout between treatment limbs ([Figure 1](#)). On the "fixed limb," patients received CPAP at the pressure predetermined by manual in-laboratory titration and were not permitted to adjust the CPAP. On the "self-adjusting" limb, patients received CPAP preset at an estimated therapeutic pressure based on a prediction formula ([20](#)) and were encouraged to adjust the pressure as necessary to maximize comfort and perceived efficacy. Upon entry, patients underwent manual in-laboratory CPAP titration by an experienced registered polysomnographic technologist during full overnight polysomnography but were not informed of the optimal CPAP derived from that study. Pretreatment measurements in each limb were made to facilitate measurement of change in outcomes within each limb and to confirm a comparable degree of disease severity before treatment between limbs.

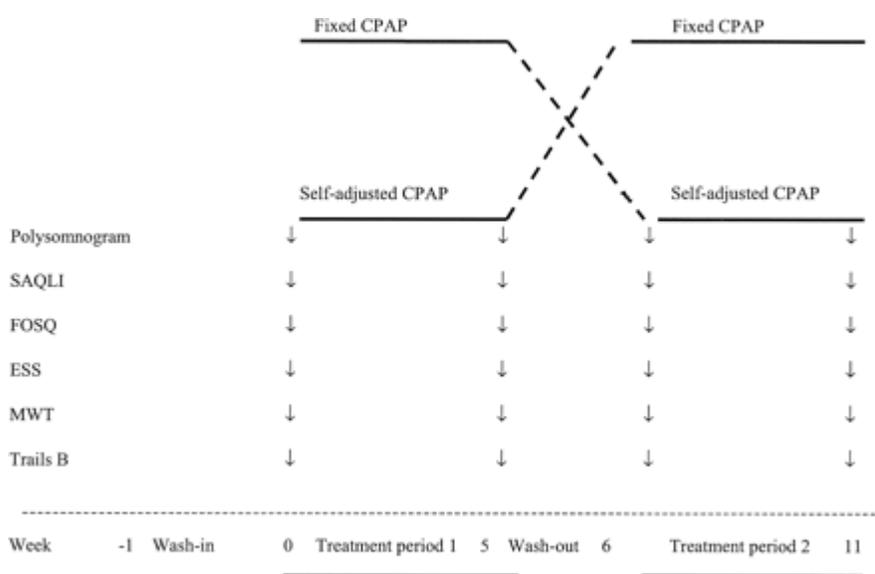


Figure 1. Schematic of study protocol. SAQLI = Sleep Apnea Quality of Life Index (21); FOSQ = Functional Outcomes of Sleep Questionnaire (22); ESS = Epworth Sleepiness Scale score (36); MWT = Maintenance of Wakefulness Test (23); Trails B = Trail-making test, part B (24).

Blinding Procedure

The pressure display on the CPAP unit was concealed throughout the fixed limb of the study with tape and adhesive that could not be removed by the patient. Sleep studies were scored blind by using a montage that excluded the CPAP signal.

Patient Education

A technologist provided 30-minutes of instruction on CPAP treatment for OSA, facial/nasal CPAP appliances, and symptoms that would suggest an incorrect CPAP setting before randomization. Patients were shown how to adjust the CPAP before the self-adjusting CPAP treatment limb.

Outcome Measures

CPAP compliance (mean hours/night), CPAP employed (cm H₂O), Apnea Hypopnea Index (AHI) ([21](#)), objective sleep architecture, Epworth Sleepiness Scale Score ([22](#)), Sleep Apnea Quality of Life Index

score (23), Functional Outcomes of Sleep Questionnaire (FOSQ) score (24), Maintenance of Wakefulness Test (40-minute version) mean sleep onset latency (25), and Trail Making B time(s) (26).

Compliance

Each CPAP unit (Aria; Resironics Inc., Pittsburgh, PA) recorded run-time, time at prescribed pressure, and the CPAP setting daily. The actual CPAP output was measured independently after each limb.

Patients

Of 28 patients approached, 24 agreed to participate in the study. Of the 24 recruited patients, 6 did not complete the study; they were 52 ± 12 years old (mean \pm SD, range 39 to 68 years), and had a mean body mass index of 37 ± 9 kg/m² (range, 29–53 kg/m²), an AHI on diagnostic sleep study of 65 ± 31 (range, 28–93), a pretreatment Epworth score of 8.5 ± 3.6 (range, 4–14), and a CPAP requirement (manual titration) of 11 ± 2.2 cm H₂O (range, 8–14 cm H₂O).

Data Analysis

The treatment effect (adjusting limb-fixed limb) estimates for each outcome were calculated using the popular method described by Fleiss (27) and others for two-period crossover studies (*see* the online supplement). This method allows for a possible period effect and is appropriate when there is an imbalance in the number of patients randomized to each sequence. Point estimates of the treatment effects are presented with the corresponding 95% confidence intervals.

RESULTS

The flow of patients through the study is illustrated in [Figure 2](#). Eighteen patients (16 males and 2 females) completed the study. These patients were 50 ± 15 years old (mean \pm SD; range, 28–78 years), had a body mass index of 36 ± 9 (range, 28–70 kg/m²), and an AHI of 40 ± 20 (range, 9–78, using thermistor as airflow signal) (21). Six patients did not complete the study. One patient withdrew for medical reasons (diagnosed with metastatic prostate cancer during the study). One patient was withdrawn when it was discovered that although his diagnostic sleep study and baseline sleep study on limb 1 both showed an AHI of more than 20; his baseline study at the start of limb 2 (off CPAP) showed no evidence of OSA. As per the study protocol, the patient had returned his CPAP unit to the investigators for the duration of the washout period. The disappearance of OSA in his case remains unexplained. However, the patient's spouse had a CPAP unit at home, and it is possible that the patient used this unit during the washout period. One patient withdrew because of nasal discomfort from CPAP treatment. Two patients withdrew because of scheduling conflicts between work and research testing. One patient chose not to provide an explanation for withdrawal from the study.

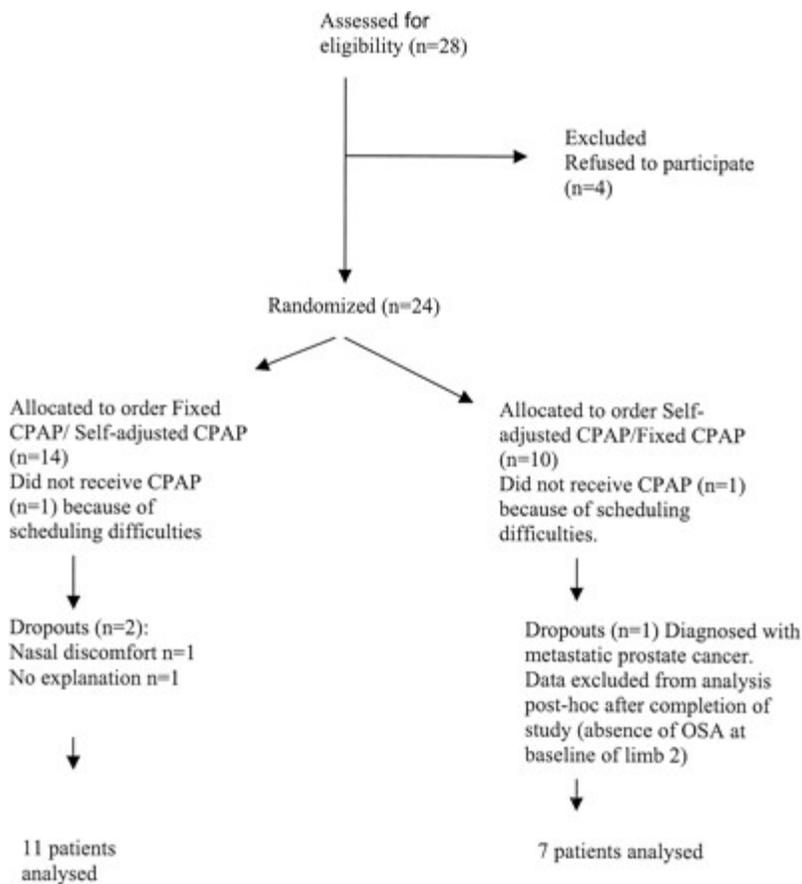


Figure 2. Flow diagram of patients through the study.

CPAP

The CPAP determined by patients to be optimal during the self-adjusting limb of the study was 10.1 ± 2.0 cm H₂O (mean \pm SD, range, 7 to 14 cm H₂O) compared with 9.7 ± 2 cm H₂O (range, 7 to 13 cm H₂O) derived by manual overnight CPAP titration in the sleep laboratory. The estimated within patient difference between these values was 0.3 (95% confidence interval, -0.6 to 1.3 cm H₂O, $p = 0.45$). The agreement between the optimal CPAP chosen by the patient and that derived by in-laboratory titration ($r = 0.62$, $p = 0.006$) is depicted in [Figure 3](#). The mean prediction equation-derived optimal CPAP (8.5 ± 0.4 cm H₂O, range, 6 to 13 cm H₂O), which was used as the starting pressure for the self-adjusting limb of the study, was significantly different from the mean self-determined optimal CPAP at the end of that treatment limb (mean difference 1.6 ± 1.2 cm H₂O; 95% confidence interval, 1 to 2.2 cm H₂O; $p < 0.0001$), but the two pressures were significantly correlated ($r = 0.82$, $p < 0.001$). Similarly, the mean prediction equation-derived CPAP differed significantly from the mean in-laboratory determined CPAP (mean difference, 1.2 ± 1.8 cm H₂O, $p = 0.012$), but the two were significantly correlated ($r = 0.63$, $p = 0.005$). On the self-adjusting CPAP limb, the average number of CPAP changes made by patients was 5.7 (SEM 1.0; range, 1 to 16). No adjustment of the CPAP occurred during the fixed limb in any patient.

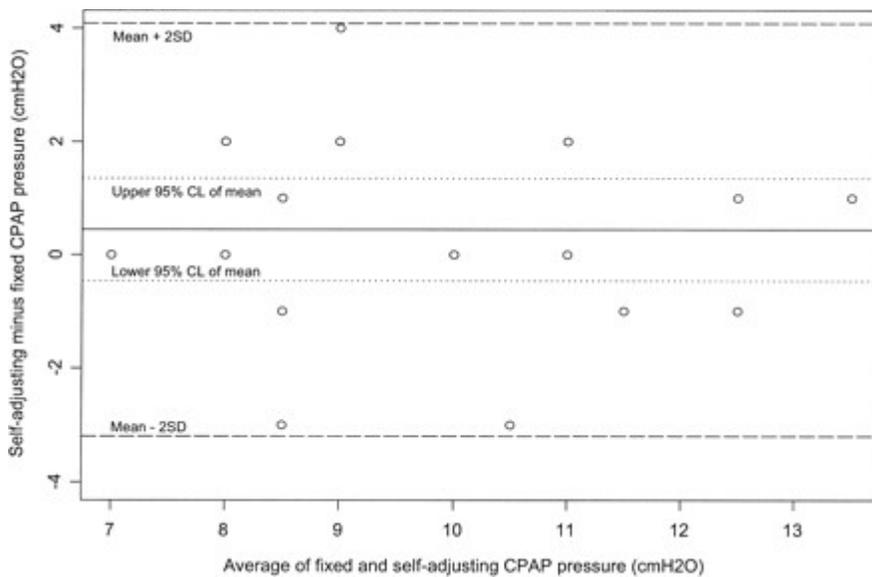


Figure 3. Bland-Altman plot illustrating the level of agreement in optimal CPAP pressure as determined by in-laboratory manual titration and by patient self-titration. CL = confidence limits.

CPAP Compliance

The average duration of CPAP use per night was not significantly different between the fixed (6.4 ± 1.2 hours) and self-adjusting (6.7 ± 1.7 hours) limbs of the study with a mean within patient difference of 0.3 (-0.6 to 1.2 hours, $p = 0.48$). CPAP was not used during an average of 1.9 ± 2.4 days on the fixed limb and 2.3 ± 3.4 days on the self-adjusting limb for a difference of 0.45 (-2.1 to 3.0 days, $p = 0.71$). Analysis of the hours of CPAP use during only those nights when the device was actually applied reveals a mean CPAP use per night on the fixed study limb of 6.7 ± 1.1 hours and on the self-adjusting limb of 7.3 ± 2.2 hours, resulting in a difference of 0.6 (-0.5 to 1.6 hours/night, $p = 0.28$). Patients used CPAP for more than 4 hours on $87 \pm 14\%$ of the fixed limb nights and $86 \pm 10\%$ of the self-adjusting limb nights.

Subjective Outcome Measures

There were significant improvements in most of the subjective outcome measures during both treatment limbs (Table 1). In particular, substantial improvements in subjective sleepiness and disease-specific quality of life were noted. However, there was no difference in the size of the improvement observed between the two treatment limbs for any of these variables.

TABLE 1. Mean values for outcome variables on each limb

Variable	Prefixed Mean \pm SD	Postfixed Mean \pm SD	Δ Fixed Mean (95% CI) p Value	Preadjusted Mean \pm SD	Postadjust Mean \pm SD	Δ Adjust Mean (95% CI) p Value	Adjusted Δ - Fixed Δ Mean (95% CI) p Value
Epworth	10.7 \pm 3.8	7.6 \pm 3.8	-3.1 (- 5.0, -1.1)	11.1 \pm 3.9	6.9 \pm 4.0	-4.2 (-6.6, -1.8)	-1.4 (-3.1, 0.4)

			0.004			0.002	0.11
			13.8 (5.4, 22.3)			11.8 (1.8, 21.8)	-3.0 (-14.8, 8.9)
FOSQ	83.9 ± 15.5	97.7 ± 17.5	0.003	83.4 ± 20.7	95.2 ± 19.8	0.024	0.60
			0.8 (0.3, 1.2)			1.1 (0.7, 1.6)	0.5 (0, 0.9)
SAQLI	4.2 ± 1.0	5.0 ± 1.2	0.002	4.3 ± 1.1	5.4 ± 0.9	0.001	0.048
			6.9 (2.3, 11.5)			10.0 (5.6, 14.5)	3.1 (-2.2, 8.4)
MWT, min	16.3 ± 8.3	23.3 ± 10	0.005	15.3 ± 9.0	25.3 ± 9.3	< 0.0001	0.24
			-1.3 (-10.7, 8.1)			-5.3 (-11.1, 0.6)	-0.04 (-0.11, 0.04)
Trail-making B, sec	65.7 ± 25	64.4 ± 28	0.77	72.6 ± 31	67.3 ± 34	0.08	0.33

Definition of abbreviations: CI = confidence interval; ESS = Epworth Sleepiness Scale score; FOSQ = Functional Outcomes of Sleep Questionnaire; MWT = Maintenance of Wakefulness Test; SAQLI = Sleep Apnea Quality of Life Index; Trails B = Trail-making Test, Part B.

Mean ± SD values for variables at the start and end of the fixed and self-adjusting CPAP treatment limbs. Δ Fixed refers to the change in the variable between the start and end of the fixed limb. Δ Adjust refers to the change in the variable between the start and end of the self-adjusted limb. Adjusted Δ -Fixed Δ refers to differences between Δ Fixed and Δ Adjust for each variable.

Objective Outcome Measures

[Table 2](#) demonstrates the overnight polysomnographic data for the 4 overnight polysomnograms performed on each of the 18 patients. There was no statistically significant difference in the change in any of the sleep variables between the two treatment limbs. The sleep stage architecture did not change significantly with either CPAP treatment limb. As expected, there were profound improvements in minimum oxygen saturation and AHI with both CPAP treatment limbs, but no significant difference between treatment limbs.

TABLE 2. Changes in sleep variables

	Prefixed	Postfixed	Preadjust	Postadjust	Adjusted Δ - Fixed Δ Mean (95% CI)
Total recording time, min	453 ± 34	465 ± 26	448 ± 35	460 ± 31	-1 (-26, 24)
Total sleep time, min	367 ± 61	385 ± 53	360 ± 73	386 ± 53	10 (-33, 52)
Sleep efficiency, %	81 ± 13	83 ± 10	80 ± 14	84 ± 9	3 (-4, 10)
Sleep onset latency, min	7.2 ± 7.4	7.4 ± 5.7	7.9 ± 6.5	7.9 ± 7.4	-0.9 (-7.8, 5.9)

REM latency, min	123 ± 73	118 ± 47	112 ± 35	106 ± 60	-13 (-31, 44)
Stage 1, %	12 ± 8	11 ± 6	11 ± 5.7	9 ± 5.7	-1.4 (-6.6, 3.9)
Stage 2, %	60 ± 11	61 ± 10	67 ± 13	62 ± 9	-4 (-11, 4)
Stages 3/4, %	4.0 ± 7.4	6.2 ± 8.6	3.1 ± 5.6	4.9 ± 7.5	-7.4 (-5.1, 3.6)
Stage REM, %	24 ± 7	22 ± 6	19 ± 8	24 ± 7	6 (-1, 13)
Time supine, % TST	41 ± 30	47 ± 28	39 ± 28	50 ± 29	0 (-30, 30)
Time right lateral, % TST	20 ± 22	20 ± 24	31 ± 26	17 ± 15	-10 (-30, 11)
Time left lateral, % TST	39 ± 32	33 ± 27	32 ± 25	32 ± 31	-10 (-30, 11)
Apnea–Hypopnea index*	43 ± 25	6 ± 6	46 ± 20	5 ± 5	-4 (-14, 7)
Minimum SaO ₂ *	75 ± 13	91 ± 4	76 ± 12	91 ± 6	1 (-7, 8)
RDI*	36 ± 19	6 ± 5	40 ± 17	5 ± 4	-4 (-13, 6)

Definition of abbreviations: CI = confidence interval; RDI = respiratory disturbance index; REM = rapid eye movement sleep; SaO₂ = oxygen saturation; TST = total sleep time.

Mean ± SD values for objective sleep variables at the start and end of the fixed and self-adjusted CPAP treatment limbs. Adjusted Δ - Fixed Δ estimates the difference between the changes in the fixed and adjusting limbs. None of these differences were significant at $\alpha = 0.05$.

* $p < 0.01$ for the change from pre to post for both fixed and self adjusting limbs.

Daytime Alertness and Trail-making Performance

CPAP treatment on both limbs of the study was accompanied by a significant improvement in objective daytime alertness, as measured by the Maintenance of Wakefulness Test ([Table 1](#)). However, there was no significant difference between treatment limbs in the mean improvement in this variable. The Trails B test score did not change significantly with treatment during either of the two study limbs, and there was no difference in the mean change in trail-making performance between the two treatment limbs.

DISCUSSION

This study demonstrates that patients with OSA are capable of effective self-titration of CPAP treatment at home. The optimal CPAPs, defined by self-titration and by manual in-laboratory titration, were similar. Improvements in both subjective and objective outcome measures were fairly consistent and were similar in magnitude between self-titration at home and manual in-laboratory CPAP titration during overnight polysomnography. There was no clinically significant difference in any measured outcome between the two CPAP treatment modalities, and compliance with CPAP treatment was highly satisfactory on both study limbs.

The observed improvements in subjective outcome measures during both treatment limbs were of similar magnitude to those previously documented with CPAP treatment in moderate and severe OSA.

Thus, the change in subjective sleepiness as measured by the Epworth Sleepiness Scale score during each treatment limb in this study was similar to that observed in clinical practice (18) and in placebo-controlled trials of CPAP treatment for OSA (5, 28, 29). The Sleep Apnea Quality of Life Index is a useful measure of disease-specific quality of life and, in particular, has the ability to incorporate negative effects of CPAP into the overall pre-to post-CPAP response (23). The size of the mean improvement in the Sleep Apnea Quality of Life Index score with CPAP treatment in both limbs of this study (0.8 units, fixed CPAP limb; 1.1 units, self-adjusted CPAP limb) represents a small but clinically significant improvement (30). There was a slightly greater improvement in Sleep Apnea Quality of Life Index score with self-adjusted CPAP than with in-laboratory titrated CPAP, but the difference between CPAP treatment modes was not clinically important. The CPAP treatment-associated change in the FOSQ (24) score observed during each limb of the current study was significant and consistent with the findings reported in other trials of CPAP treatment for OSA (28, 29). Thus, patients with mild OSA had fewer symptoms (a higher baseline pretreatment FOSQ score, mean $101 \pm \text{SD}$) (18) and a smaller response to CPAP treatment (mean post-CPAP treatment FOSQ score, 106 ± 18) than that observed during either CPAP treatment limb in this study (29), whereas patients with more severe OSA tended to have a more symptoms (a lower pre-CPAP FOSQ score, mean $\pm \text{SEM}$, 84.5 ± 4.63) and a larger pre- to post-CPAP treatment response in FOSQ score (post-CPAP score, 109.4 ± 2.6) (28) than that observed in this study. The magnitude of the improvement in subjective outcome measures with either CPAP treatment limb in this study, therefore, was at least as great as that which might have been predicted, based on published literature in similar patient groups with OSA, suggesting that both treatment limbs provided effective symptomatic treatment to this patient group. However, it is important to understand that this patient group was not selected on the basis of symptom severity and included several patients who had few daytime symptoms; if subjective outcomes had been the most important outcome measures, then the presence of significant daytime symptoms related to OSA would have been an essential inclusion criterion.

Most objective outcome measures also improved significantly with either method of CPAP treatment. The Maintenance of Wakefulness Test (31, 32) was employed as a measure of daytime alertness in this study, as evidence suggests that it is a more valid measure of sleepiness/alertness in OSA than the Multiple Sleep Latency Test (31–33). Using the one-epoch criterion for sleep onset and the 40-minute version of the test, patients were clearly objectively somnolent pretreatment on both limbs of the study, but voluntary alertness improved into the normal range (25) with treatment, as expected. Trail-making B performance, a test of higher executive function, has demonstrated sensitivity in some previous studies to the effects of sleep apnea (26) and to CPAP treatment versus placebo (34) but did not show any significant change with CPAP treatment in this study. However, the finding of improved trail-making performance with treatment of OSA has not been a consistent one (35), with several studies demonstrating no change in Trail-making performance with treatment of OSA, despite unequivocal treatment-related improvements in several other domains. Therefore, it would be unreasonable to extrapolate from the negative trail-making performance response to CPAP treatment in this study to other domains of cognitive performance that were not measured in this study.

The disparity between the aforementioned improvements in subjective and objective outcome measures and the lack of change in any objective measures of sleep architecture with CPAP treatment in this study is surprising. There was a marked improvement in sleep continuity associated with reduction in the AHI and also a marked improvement in the nadir of the oxygen saturation during sleep with treatment. One might have expected a coincident increase in slow wave sleep and rapid eye movement sleep with this magnitude of improvement in sleep-disordered breathing (21). The lack of improvement in objectively measured sleep stage architecture with CPAP treatment in this study is not easy to explain. The noise to signal ratio of in-laboratory recordings could potentially have interfered with the

ability to detect changes in sleep architecture, but the recording equipment and environment used in this study were standard for clinical sleep studies and were similar to those employed in other studies that have demonstrated improvements in objective sleep architecture in patients with OSA with CPAP treatment. Others have described improvements in symptoms and daytime performance in patients with OSA treated with CPAP, in the absence of any objective improvement in sleep architecture (6), but this finding is not typical. This study was not specifically designed to examine differences in sleep stage architecture with treatment (sleep stage data were required to calculate the pretreatment and post-treatment AHIs and were therefore reported). McArdle and Douglas, in a placebo-controlled crossover study of 22 patients, designed to analyze the sleep architectural changes associated with treatment of OSA, demonstrated a doubling of slow wave sleep, halving of stage 1 sleep, and a nonsignificant increase in REM sleep with CPAP treatment (36). *Post hoc* statistical power analysis reveals that this study had 90% power ($\alpha = 0.05$) to detect a change of 5% in the proportion of total sleep time spent in slow wave sleep pre- to post-CPAP on either treatment limb or between the two post-CPAP nights in this study (an amount similar to the mean difference observed by McArdle and Douglas between CPAP and placebo). However, there was more variability in the percentage of time spent in stage 1 sleep pre- to post-CPAP treatment in this study. The *post hoc* power estimate suggests that a difference of 8% in the proportion of total sleep time spent in stage 1 sleep comparing pre- to post-CPAP and comparing the two post-CPAP nights would be required to provide 90% statistical power ($\alpha = 0.05$) in this study; this is a larger change than that observed by McArdle and Douglas. Hence, an inadequate sample size may underlie the apparent lack of improvement in some aspects of sleep architecture in this study.

The use of a crossover design increased statistical power to detect differences in the primary outcome variables of this study, but the major motivation for this design was to eliminate the effect of interindividual differences on study outcomes, particularly CPAP compliance. CPAP compliance among patients with OSA is a complex issue. Although severity of disease and improvement in daytime somnolence with treatment have been demonstrated to be important factors in determining CPAP compliance (37), interindividual attitudes and preferences appear to be even more predominant in this regard (19). Thus, despite a wealth of literature on factors associated with either satisfactory or poor CPAP compliance among patients with OSA, it remains very difficult to predict CPAP compliance in a given patient with OSA. This fact has fuelled enthusiasm for a purely pragmatic approach to CPAP treatment in OSA: A short individual clinical trial of CPAP has been advocated as the best way of determining the likelihood of acceptable CPAP compliance in a given individual (38). Whereas an intraindividual crossover design eliminated concerns about dominant interindividual differences in attitude to and acceptance of CPAP treatment, it also opened up other potential sources of bias in this study. In particular, acclimatization to CPAP treatment in the first study limb could have biased toward a greater treatment effect in the second study limb, and a carryover effect between treatment limbs could have reduced the treatment effect on the second treatment limb. We attempted to address these potential sources of bias by (1) designing a washout period between treatment limbs that would eliminate any likelihood of a carryover effect, (2) randomizing the treatment order between patients, (3) including possible order effects in the data analysis when comparing outcomes between treatment limbs, (4) making baseline pretreatment measurements at the start of each treatment limb to document any change in pretreatment disease severity between study limbs, and (5) comparing the pretreatment to post-treatment change in relevant variables rather than simply comparing the post-treatment values for each variable. There are, of course, other cost-efficient methods of introducing CPAP treatment to patients with OSA. For patients with more severe OSA, split-night studies (where the overnight study is partitioned into an initial diagnostic part and then, after the diagnosis of OSA has been objectively confirmed, CPAP titration is performed) have proven feasible (9, 39). CPAP titration can also be undertaken by automated CPAP treatment devices, and those devices that base the change in CPAP on changing airflow contour may provide a satisfactory estimation of the therapeutic CPAP in

some patients (40–42) Automated CPAP titration devices do not appear to have any advantage over conventional fixed CPAP in the routine treatment of OSA (43–45) and may not compensate appropriately for changes in nasal resistance (8). A strategy that empowers the patient with OSA with the freedom to alter CPAP appropriately in response to altered upper airway physiology is inexpensive and may prove advantageous in the latter situation and in the long-term management of the patient. To date, detailed objective measures of daytime performance in patients with OSA after automated CPAP titration have not been reported, and there is no available information, of course, on the relative merits of self-titration of CPAP versus automated CPAP titration.

In considering the findings of this study, it is important to appreciate that the protocol required each patient to undergo a manual in-laboratory CPAP titration after randomization. It is likely that patients derived some benefit from the presence of a sleep technologist during this initial exposure to CPAP. Indeed, there is very clear evidence that even minor initial efforts at encouragement and education of the patient with sleep apnea may influence subsequent CPAP compliance (46, 47). Patients in this study also received 30 minutes of education about sleep apnea and CPAP treatment and a phone call from a research assistant on each study limb. The latter level of patient education and support, which is equivalent to the routine allotment of time for education of each patient with a new diagnosis of OSA in our clinical practice, may nonetheless account for the superior CPAP compliance observed during both limbs of this study as compared with other similar controlled trials of CPAP treatment in OSA (4, 6, 48, 49). Hence, it is important not to misconstrue the findings of this study as obviating the need for education and support of the patient with OSA undergoing CPAP treatment. Rather, the study demonstrates that in combination with a modest amount of educational support (a time commitment from a clinical assistant that would, hopefully, be feasible in routine clinical practice), the patient with OSA is just as capable of performing an effective CPAP self-titration as a technologist during overnight polysomnography. Although the self-determined optimal CPAP sometimes varied widely from the prediction equation–derived CPAP and the two mean pressures were significantly different in this study, the prediction equation may have provided a useful starting point for patient self-titration because it tended on average to slightly underestimate the optimal CPAP. One could speculate that there may be some advantage to starting with a slightly lower than optimal CPAP rather than too high of a CPAP in that the patient is protected from the discomfort associated with higher CPAPs, and this may have contributed to the high degree of patient compliance with CPAP during the self-adjusted CPAP treatment period in this study.

The AHI measured in this study was based on a thermistor measure of airflow. This measure, although it yields a useful threshold (AHI of 5) between minimum clinically relevant disease and normal (21), is less sensitive in the detection of airflow limitation than the nasal cannula pressure transducer (50). For that reason, the thermistor may underestimate disease severity; it is important to bear this fact in mind when extrapolating the findings of this study to patients whose sleep apnea diagnosis is based on a nasal cannula pressure transducer airflow signal and who may have milder OSA than the patients in this study. The study protocol empowered each patient with the knowledge and capability of directing his or her own CPAP treatment during the self-adjusted CPAP treatment limb. This strategy has not previously been employed in CPAP treatment of OSA, but systematic evaluations of similar management approaches for other medical disorders have generated very positive findings and have been demonstrated to facilitate cost-effective treatment of those conditions (16, 51–53). Because CPAP compliance is already known to be sensitive to patient education, it would be unethical and clinically unhelpful to have conducted a placebo-controlled study of this educational intervention. The very satisfactory CPAP compliance rate with the conventional approach to CPAP prescription in this study provided a suitably high treatment standard against which to evaluate self-directed CPAP therapy and provided information that will, hopefully, be useful in clinical practice. The study was adequately

powered to detect clinically meaningful differences between the two CPAP treatment strategies. One shortcoming of this study is the relatively short duration of the treatment protocol; although the results are promising, they cannot be extrapolated to long-term clinical outcomes. A randomized parallel group study with a longer treatment duration, and with both clinical and health-economic outcomes, would be required to assess whether such a treatment strategy can provide significant economic advantages without compromise of the standard of care for patients with OSA.

In summary, this study demonstrates that self-titration of CPAP in patients with OSA is as efficacious as manual titration in a sleep laboratory, with similar subjective and objective outcomes, and CPAP compliance. Clearly, for this strategy to be successful, the patient must understand when and how to change the CPAP. Although the patient population studied did include a wide age range, this strategy would not be feasible for intellectually disadvantaged patients and those with physical handicaps that would severely limit vision and/or manual dexterity. Nonetheless, the findings from this study imply that routine overnight polysomnography is unnecessary for the purpose of CPAP titration in many patients with OSA, provided that the patient is given some basic education and support. Resources currently allocated to manual in-laboratory CPAP titration might be better spent on specific attention to patient education and support rather than pressure titration. A treatment algorithm that focuses on such ambulatory patient education and support rather than in-laboratory CPAP titration may realize significant efficiencies in the management of OSA without loss of treatment efficacy.

References

1. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Bader S. The occurrence of sleep disordered breathing in middle-aged adults. *N Engl J Med* 1993;328:1230–1235.[\[Abstract/Free Full Text\]](#)
2. Ronald J, Delaive K, Roos L, Manfreda J, Bahammam A, Kryger MH. Health care utilization in the 10 years prior to diagnosis in obstructive sleep apnea syndrome patients. *Sleep* 1999;22:225–229.[\[Medline\]](#)
3. Sullivan CE, Issa FG, Berthon-Jones M, Eves L. Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. *Lancet* 1981;1:862–865.[\[Medline\]](#)
4. Engleman HM, Martin SE, Deary IJ, Douglas NJ. Effect of continuous positive airway pressure treatment on daytime function in sleep apnoea/hypopnoea syndrome. *Lancet* 1994;343:572–575.[\[CrossRef\]](#)[\[Medline\]](#)
5. Engleman HM, Kingshott RN, Wraith PH, Mackay TW, Deary IJ, Douglas NJ. Randomized placebo-controlled crossover trial of continuous positive airway pressure for mild sleep apnea/hypopnea syndrome. *Am J Respir Crit Care Med* 1999;159:461–467.[\[Abstract/Free Full Text\]](#)
6. Redline S, Adams N, Strauss ME, Roebuck T, Winters M, Rosenberg C. Improvement of mild sleep-disordered breathing with CPAP compared with conservative therapy. *Am J Respir Crit Care Med* 1998;157:858–865.[\[Abstract/Free Full Text\]](#)
7. Smith PL, Hudgel DW, Olsen LG, Partinen M, Rapoport DM, Rosen CL, Skatrud JB, Waldhorn RE, Westbrook PR, Young T. Indications and standards for the use of nasal continuous positive airway pressure (CPAP) in sleep apnea syndromes. *Am J Respir Crit Care Med* 1994;150:1738–1745.[\[Medline\]](#)

8. Lafond C, Series F. Influence of nasal obstruction on auto-CPAP behaviour during sleep in sleep apnoea/hypopnoea syndrome. *Thorax* 1998;53:780–783.[\[Abstract/Free Full Text\]](#)
9. Sanders MH, Black J, Constantino JP, Kern N, Studnicki K, Coates J. Diagnosis of sleep-disordered breathing by half-night polysomnography. *Am Rev Respir Dis* 1991;144:1256–1261.[\[Medline\]](#)
10. Rolfe I, Olson LG, Saunders NA. Long-term acceptance of continuous positive airway pressure in obstructive sleep apnea. *Am Rev Respir Dis* 1991;144:1130–1133.[\[Medline\]](#)
11. Krieger J. Long term compliance with nasal continuous positive airway pressure in obstructive sleep apnea. *Sleep* 1992;15:S42–S46.[\[Medline\]](#)
12. Pepin JL, Leger P, Veale D, Langevin B, Robert D, Levy P. Side effects of nasal continuous positive airway pressure in sleep apnea syndrome. *Chest* 1995;107:375–381.[\[Abstract/Free Full Text\]](#)
13. Barrone Kribbs NB, Pack AI, Kline LR, Smith PL, Schwartz AR, Schubert NM, Redline S, Henry JN, Getsy JE, Dinges DF. Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea. *Am Rev Respir Dis* 1993;147:887–895.[\[Medline\]](#)
14. Hoy CJ, Vennelle M, Kingshott RN, Engleman HM, Douglas NJ. Can intensive support improve continuous positive airway pressure use in patients with the sleep apnea/hypopnea syndrome? *Am J Respir Crit Care Med* 1999;159:1096–1100.[\[Abstract/Free Full Text\]](#)
15. Krieger J, Sforza E, Petiau C, Weiss T. Simplified diagnostic procedure for obstructive sleep apnea: lower subsequent compliance with CPAP. *Eur Respir J* 1998;12:776–779.[\[Abstract\]](#)
16. Hennessy-Harstad EB. Empowering adolescents with asthma to take control through adaptation. *J Pediatr Health Care* 1999;13:273–277.[\[Medline\]](#)
17. Anstead M, Phillips B, Buch K. Tolerance and intolerance to continuous positive airway pressure. *Curr Opin Pulm Med* 1998;4:351–354.[\[Medline\]](#)
18. Lacassagne L, Didier A, Doussau S, Murriss-Espin M, Birot P, Charlet JP, Thach KS, Tiberge M, Paoli JR, Pessey JJ, *et al.* Results of 248 patients with sleep apnea syndrome treated by continuous positive pressure ventilation between 1990 and 1995: a study of compliance and outcome of the apnea-hypopnea index. *Rev Mal Respir* 2000;17:467–474.[\[Medline\]](#)
19. Berry RB. Improving CPAP compliance: man more than machine. *Sleep Med* 2000;1:175–178.[\[CrossRef\]](#)[\[Medline\]](#)
20. Hoffstein V, Mateika S. Predicting nasal continuous positive airway pressure. *Am J Respir Crit Care Med* 1994;50:486–488.
21. 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* 1999;22:667–689.[\[Medline\]](#)
22. Johns MW. A new method for measuring daytime sleepiness: the Epworth Sleepiness Scale. *Sleep* 1991;14:540–545.[\[Medline\]](#)

23. Flemons WW, Reimer MA. Development of a disease-specific health-related quality of life questionnaire for sleep apnea. *Am J Respir Crit Care Med* 1998;158:494–503.[\[Abstract/Free Full Text\]](#)
24. Weaver TE, Laizner AM, Evans LK, Maislin G, Chugh DK, Lyon K, Smith PL, Schwartz AR, Redline S, Pack AI, *et al.* An instrument to measure functional status outcomes for disorders of excessive sleepiness. *Sleep* 1997;20:835–843.[\[Medline\]](#)
25. Doghramji K, Mitler MM, Sangal RB, Shapiro C, Taylor S, Walsleben J, Belisle C, Erman MK, Hayduk R, Hosn R, *et al.* A normative study of the maintenance of wakefulness test. *Electroencephalogr Clin Neurophysiol* 1997;103:554–562.[\[CrossRef\]](#)[\[Medline\]](#)
26. Reitan RM. Trail-making test results for normal and brain damaged children. *Percept Mot Skills* 1971;33:575–581.[\[Medline\]](#)
27. Fleiss JL. The design and analysis of clinical experiments. New York: Wiley; 1986.
28. Monserrat JM, Monserrat F, Hernandez L, Farre R, Vilagut G, Navajas D, Badia JR, Carrasco E, de Pablo J, Ballester E, *et al.* Effectiveness of CPAP treatment in daytime function in sleep apnea syndrome. *Am J Respir Crit Care Med* 2001;164:608–613.[\[Abstract/Free Full Text\]](#)
29. Monasterio C, Vidal S, Duran J, Ferrer M, Carmona C, Barbe F, Mayos M, Gonzalez-Mangado N, Monserrat J, Navarro A, *et al.* Effectiveness of continuous positive airway pressure in mild sleep apnea-hypopnea syndrome. *Am J Respir Crit Care Med* 2001;164:939–943.[\[Abstract/Free Full Text\]](#)
30. Flemons WW, Reimer MA. Measurement properties of the Calgary Sleep Apnea Quality of Life Index. *Am J Respir Crit Care Med* 2002;165:159–164.[\[Abstract/Free Full Text\]](#)
31. Poceta JS, Timms RM, Jeong D, Ho S, Erman MK, Mitler MM. Maintenance of wakefulness test in obstructive sleep apnea syndrome. *Chest* 1992;101:893–897.[\[Abstract/Free Full Text\]](#)
32. Mitler MM, Gujavarty KS, Browman CP. Maintenance of wakefulness test: a polysomnographic technique for evaluating treatment efficacy in patients with excessive somnolence. *Electroencephalogr Clin Neurophysiol* 1982;53:658–661.[\[CrossRef\]](#)[\[Medline\]](#)
33. Johns MW. Sensitivity and specificity of the multiple sleep latency test (MSLT), the maintenance of wakefulness test, and the Epworth sleepiness scale: failure of the MSLT as a gold standard. *J Sleep Res* 2000;9:5–11.[\[CrossRef\]](#)[\[Medline\]](#)
34. Henke KG, Grady JJ, Kuna ST. Effect of nasal continuous positive airway pressure on neuropsychological function in sleep apnea-hypopnea syndrome: a randomized, placebo-controlled trial. *Am J Respir Crit Care Med* 2001;163:911–917.[\[Abstract/Free Full Text\]](#)
35. Barnes M, Houston D, Worsnop CJ, Neill AM, Mykytyn AK, Trinder J, Saunders NA, McEvoy RD, Pierce RJ. A randomized controlled trial of continuous positive airway pressure in mild obstructive sleep apnea. *Am J Respir Crit Care Med* 2002;165:773–780.[\[Abstract/Free Full Text\]](#)
36. McArdle N, Douglas NJ. Effect of continuous positive airway pressure on sleep architecture in the sleep apnea-hypopnea syndrome: a randomized controlled trial. *Am J Respir Crit Care Med* 2001;164:1459–1463.[\[Abstract/Free Full Text\]](#)

37. McArdle N, Devereux G, Heidarnejad H, Engleman HM, Mackay TW, Douglas NJ. Long-term use of CPAP therapy for sleep apnea/hypopnea syndrome. *Am J Respir Crit Care Med* 1999;159:1108–1114.[\[Abstract/Free Full Text\]](#)
38. Popescu G, Latham M, Allgar V, Elliott MW. Continuous positive airway pressure for sleep apnoea/hypopnoea syndrome: usefulness of a 2 week trial to identify factors associated with long term use. *Thorax* 2001;56:727–733.[\[Abstract/Free Full Text\]](#)
39. Fleury B, Rakotonanahary D, Tehindrazanarivelo AD, Hausser-Hauw C, Lebeau B. Long-term compliance to continuous positive airway pressure therapy (nCPAP) set up during a split-night polysomnography. *Sleep* 1994;17:512–515.[\[Medline\]](#)
40. Teschler H. Autoset nasal CPAP titration: constancy of pressure, compliance and effectiveness at 8 month follow-up. *Eur Respir J* 1997;10:2073–2078.[\[Abstract\]](#)
41. Series F, Marc I. Efficacy of automatic continuous positive airway pressure therapy that uses an estimated required pressure in the treatment of the obstructive sleep apnea syndrome. *Ann Intern Med* 1997;127:588–595.
42. Randerath WJ, Schraeder O, Galetke W, Feldmeyer F, Ruhle KH. Autoadjusting CPAP therapy based on impedance: efficacy, compliance and acceptance. *Am J Respir Crit Care Med* 2001;163:652–657.[\[Abstract/Free Full Text\]](#)
43. Stradling J, Barbour C, Pitson DJ, Davies RJ. Automatic nasal continuous positive airway pressure titration in the laboratory: patient outcomes. *Thorax* 1997;52:72–75.[\[Abstract\]](#)
44. d'Ortho MP, Grillier-Lanoir V, Levy P, Goldenberg F, Corriger E, Harf A, Lofaso F. Constant vs. automatic continuous positive airway pressure therapy: home evaluation. *Chest* 2000;118:1010–1017.[\[Abstract/Free Full Text\]](#)
45. Boudewyns A, Grillier-Lanoir V, Willemen MJ, De Cock WA, Van de Heyning PH, De Backer WA. Two months follow up of auto-CPAP treatment in patients with obstructive sleep apnoea. *Thorax* 1999;54:147–149.[\[Abstract/Free Full Text\]](#)
46. Chervin RD, Theut S, Bassetti C, Aldrich MS. Compliance with nasal CPAP can be improved by simple Interventions. *Sleep* 1997;20:284–289.[\[Medline\]](#)
47. Likar LL, Panciera TM, Erickson DA, Rounds S. Group education sessions and compliance with nasal CPAP therapy. *Chest* 1997;111:1273–1277.[\[Abstract/Free Full Text\]](#)
48. Engleman HM, Martin SE, Kingshott RN, Mackay TW, Deary IJ, Douglas NJ. Randomised placebo-controlled trial of daytime function after continuous positive airway pressure (CPAP) therapy for the sleep apnea/hypopnea syndrome. *Thorax* 1998;53:341–345.[\[Abstract/Free Full Text\]](#)
49. Ballester E, Badia JR, Hernandez L, Carrasco E, de Pablo J, Fornas C, Rodriguez-Roisin R, Montserrat JM. Evidence of the effectiveness of continuous positive airway pressure in the treatment of sleep apnea/hypopnea syndrome. *Am J Respir Crit Care Med* 1999;159:495–501.[\[Abstract/Free Full Text\]](#)
50. Norman RG, Ahmed MM, Walsleben JA, Rapoport DM. Detection of respiratory events during NPSG: nasal cannula/pressure sensor versus thermistor. *Sleep* 1997;20:1175–1184.[\[Medline\]](#)

51. Metcalf C. Stoma care: empowering patients through teaching practical skills. *Br J Nurs* 1999;8:593–600.[\[Medline\]](#)
52. Lorig KR, Sobel DS, Ritter PL, Laurent D, Hobbs M. Effect of a self-management program on patients with chronic disease. *Eff Clin Pract* 2001;4:256–262.[\[Medline\]](#)
53. Robinson A, Thompson DG, Wilkin D, Roberts C. Guided self-management and patient-directed follow-up of ulcerative colitis: a randomized trial. *Lancet* 2001;358:976–981.[\[CrossRef\]](#)[\[Medline\]](#)

Automatic CPAP titration with different self-setting devices in patients with obstructive sleep apnoea

A. Stammnitz, A. Jerrentrup, T. Penzel, J.H. Peter, C. Vogelmeier, H.F. Becker#ERS Journals Ltd 2004.

ABSTRACT: Autotitrating continuous positive airway pressure (CPAP) devices automatically adjust the pressure according to upper airway obstructions. The aim of this study was to compare the treatment effects of different automatic CPAP devices (AutoSet, Horizon and Virtuoso) with conventional CPAP in patients with obstructive sleep apnea independently of financial manufacturer support.

Twelve male patients with obstructive sleep apnoea were submitted to a crossover study protocol with overnight polysomnography for 6 consecutive nights. After diagnostic polysomnography, the CPAP pressure was manually titrated. Over the next 4 nights, the patients were treated with any one of the three automatic CPAP devices or fixed CPAP in random order.

The apnea/hypopnea index on the diagnostic night was 67.3 ± 21.7 events $\cdot h^{-1}$, and was significantly reduced to 0.7 ± 1.2 , $3.02 \pm .9$, 2.3 ± 2.5 and 12.0 ± 13.6 events $\cdot h^{-1}$, with the fixed CPAP, AutoSet, Horizon and Virtuoso devices respectively. An apnea/hypopnea index of <5 events $\cdot h^{-1}$, an indicator of optimal treatment, was achieved in all patients with fixed CPAP and in 10 patients using the AutoSet and Horizon devices, but in only six of the 12 using the Virtuoso. The mean pressure was significantly lower with the AutoSet and Virtuoso devices, but not with the Horizon as compared to fixed CPAP. The maximum pressure was significantly higher with the Horizon.

It is concluded that automatic continuous positive airway pressure devices produce a significant reduction in apnea/hypopnea index; however, there is considerable difference in the efficacy of the various devices.

Nasal continuous positive airway pressure (nCPAP) is the therapy of choice for patients with moderate-to-severe symptomatic sleep apnea [1, 2] as it has been shown to improve quality of life [3] and cardiovascular risk factors such as arterial hypertension [4, 5] in controlled trials. The pressure applied during long-term treatment is generally determined by a technician in the sleep laboratory on the basis of a continuous polysomnographic recording. The treatment pressure is increased until

apneas, hypopneas and snoring are prevented during all sleep stages and in the supine position. This fixed pressure is then used for home therapy. During the course of the night, the pressure that is needed to prevent upper airway obstruction varies according to the severity of upper airway obstruction, body position, sleep stage and other factors, such as nasal congestion and alcohol consumption [6–9]. Automatic CPAP devices were designed to increase the applied pressure when airway obstruction or snoring occurs and lower the pressure when the patient is awake or no obstruction occurs. The process of pressure titration might be simplified by these devices, thus saving time and costs.

The performance of automatic nCPAP devices can be evaluated by means of both bench studies and clinical studies. Bench studies testing the response of the device to numerous well-defined events under controlled conditions are essential during the developmental process before patients are treated. Clinical studies are then necessary to demonstrate that the device functions appropriately in clinical practice, where a variety of factors may disturb the algorithm of the device.

The clinical studies published to date have tested the performance of a single device of the manufacturer sponsoring the study against no treatment [10–12], the pressure determination night [12–14] or fixed nCPAP [12, 15]. The aim of the present study, therefore, was to compare the effectiveness of the three most frequently used automatic nCPAP devices in Germany (AutoSet™; ResMed, San Diego, CA, USA; Horizon; DeVilbiss Sunrise Medical, Inc., Carlsbad, CA, USA; and Virtuoso; Respironics, Inc., Murrysville, PA, USA) with fixed nCPAP using a crossover protocol independently of financial manufacturer support.

Methods

Patients and protocol

Over a period of 6 months, one patient per week could be studied. Each Tuesday, one patient with documented obstructive or mixed sleep apnoea (apnea/hypopnea index (AHI) of ≥ 10 events/h) in the diagnostic sleep study of the preceding night was asked to participate. If there was more than one eligible patient, patients were asked in alphabetical order. Thus, a group of consecutive unselected patients with moderate-to-severe obstructive and mixed sleep apnea who commenced nCPAP treatment were studied. Exclusion criteria were predominantly central apneas, allergic rhinitis, upper airway infection, hypercapnic respiratory failure (arterial carbon dioxide tension of ≥ 6.7 kPa (≥ 50 mmHg)), heart failure (New York Heart Association Functional Class III–IV), claustrophobia or malignancy. Sixteen of the eligible patients consented to participate (one female and 15 males, aged 52 ± 7.9 yrs (mean \pm SD), with a body mass index of 32.3 ± 4.0 kg·m⁻²).

After the diagnostic sleep study, the patients received detailed information concerning nCPAP treatment, an appropriate nasal mask was chosen and the patients then tested fixed nCPAP at different pressure levels for ~ 1 h during wakefulness until they felt comfortable breathing with the device.

All patients underwent manual CPAP titration during the second night. Over the following 4 polysomnographic study nights, the patients were treated in random order with one of three different self-adjusting CPAP devices or with fixed CPAP using the effective pressure that had been manually titrated. Four patients did not complete the study: three patients did not want to continue as they could not tolerate the unnecessarily high mask pressure during automatic CPAP (one patient each on the Virtuoso, Horizon and AutoSet devices) and one patient did not want to continue because he could not exhale with fixed nCPAP. The results of the 12 patients that completed the study are presented here.

The study protocol was approved by the ethics committee of Philipps University Marburg (Marburg an der Lahn, Germany), and all patients gave their written informed consent before inclusion in the study.

Sleep studies

The following parameters were recorded continuously using chart recorders (ED-16 and UD-8; Madaus Schwarzer, Munich, Germany): electroencephalography (2 leads (C3/A2 and C4/A1)), electrooculography (2 leads), electromyography (chin), thoracic and abdominal movements by means of inductive plethysmography (Respirace; Ambulatory Monitoring, Ardsley, NY, USA), oronasal airflow by means of thermistors, arterial oxygen saturation (S_{a,O_2}) by means of finger oximetry (Nellcor, Hayward, CA, USA), and 1-channel electrocardiography. Snoring was detected with a surface microphone placed over the trachea.

CPAP therapy was introduced the night after the diagnostic study. All patients received CPAP via a nasal mask. The nasal mask was selected individually, and all patients used the same interface for all treatment nights. Instead of oronasal airflow, the pressure at the nasal mask was recorded using a piezoelectric pressure sensor (Sensortechnics, Puchheim, Germany) during the treatment nights.

Continuous positive airway pressure titration

Manual titration

The CPAP titration was started with the pressure set at 4 cmH₂O. During sleep, the pressure was increased in steps of 1 cmH₂O, until apneas, hypopneas and snoring were prevented during all sleep stages and in the supine position. This pressure was used for fixed nCPAP.

Automatic titration

Automatic titration was performed with the AutoSet, Horizon and Virtuoso devices. The AutoSet and Horizon utilize a pneumotachograph to detect flow limitation, snoring and apneas.

The Virtuoso device uses a pressure transducer to detect vibrations that occur together with apneas, hypopneas and snoring. In the present study, no upper or lower pressure limits were set.

Data analysis

The diagnostic night and the treatment nights were evaluated. Sleep stages were scored in 30-s epochs according to the criteria of RECHTSCHAFFEN and KALES [16]. An apnoea was defined as the cessation of oronasal airflow for ≥ 10 s. A hypopnea was defined as a reduction in oronasal airflow by $\geq 50\%$ lasting for ≥ 10 s, accompanied by a decrease in $S_{a,O_2} \geq 4\%$ of the preceding stable S_{a,O_2} . The number of apneas plus hypopneas per hour of sleep was calculated and reported as the AHI.

Arousal was defined according to American Sleep Disorders Association criteria [17]. The number of all electroencephalographic arousals per hour of sleep was defined as the total arousal index. The respiratory arousal index was defined as the number of respiratory disturbances (apneas, hypopneas and snoring episodes) accompanied by electroencephalographic arousal per hour of sleep. Non-respiratory arousals were calculated as the difference between the total arousal index and the respiratory arousal index. The arousal-after-pressure elevation index was defined as the number of electroencephalographic arousals that occurred after a pressure elevation of the automatic CPAP devices per hour of sleep.

S_{a,O_2} was recorded continuously and minimal, maximal and mean S_{a,O_2} , as well as the percentage of total sleep time (TST) spent at an S_{a,O_2} of < 90%, were calculated.

Mask pressure was continuously recorded and minimal, maximal and mean mask pressure, as well as the percentage of TST spent with a mask pressure greater than that of fixed CPAP, were calculated.

The evaluation was performed by an experienced technician otherwise not involved in the study.

Statistical analysis

Data were computed as mean \pm SD for descriptive purposes. The different treatment modalities were compared using Friedman's test. Pairwise comparisons were carried out by means of the Wilcoxon test. Significance was assumed at a p-value of < 0.05.

Results

Respiratory disturbances

Mean AHI was significantly decreased with fixed CPAP and all of the automatic CPAP devices (fig. 1). The AHI with fixed CPAP was significantly lower than with all of the automatic nCPAP devices. The AHI with the AutoSet and Horizon devices was significantly lower than with the Virtuoso. An AHI of < 5 events \cdot h⁻¹, an indicator of optimal treatment, was seen in all patients using fixed CPAP and in 10 of the 12 patients with the Horizon and AutoSet devices, but in only six of the 12 patients with the Virtuoso.

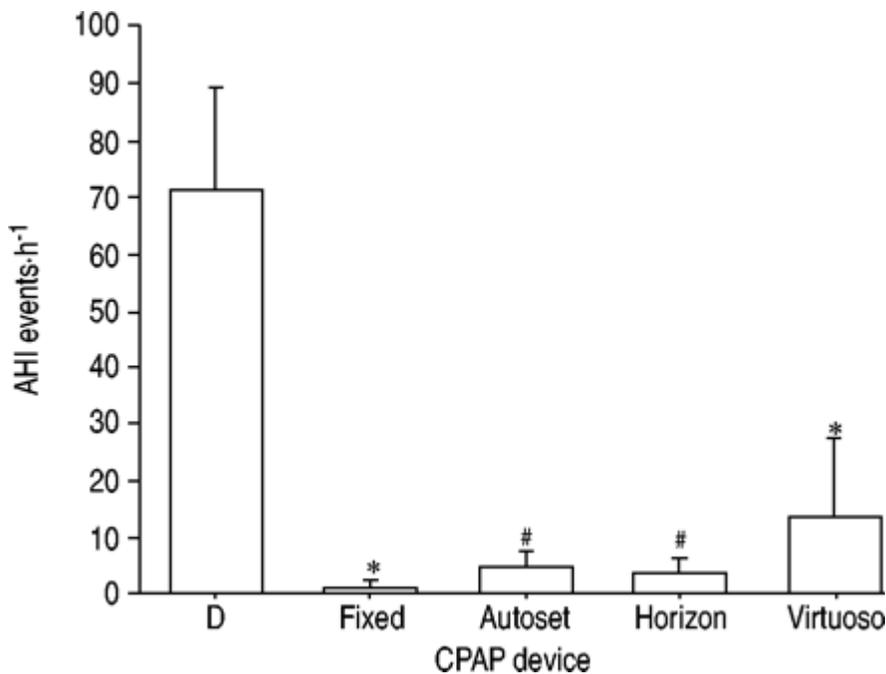


Fig. 1.— Apnoea/hypopnoea index (AHI) during the diagnostic (D) and treatment nights using various continuous positive airway pressure (CPAP) devices. Data are presented as mean \pm sd. *: p<0.05 versus all other groups; #: p<0.05 versus diagnostic night, fixed CPAP and Virtuoso.

Sleep structure

Table 1 shows the TST and sleep stage distribution of the diagnostic and treatment nights. The TST was not significantly different on any of the 5 study nights. The stage 3–4 nonrapid eye movement and rapid eye movement sleep stages increased on all 4 treatment nights compared to the diagnostic night. No significant differences concerning sleep stages were found between fixed CPAP and the automatic CPAP devices.

Table 1— Total sleep time (TST) and sleep stages of the diagnostic and treatment nights

	Diagnostic night	Fixed CPAP	Automatic CPAP		
TST min	363.7±61.4	374.6±86.5	339.2±66.7	356.5±52.6	339.5±51.3
NREM %					
Stage 1	14.9±12.0	8.0±5.5*	9.7±6.2*	9.1±6.6*	11.2±5.4
Stage 2	70.2±11.8	52.3±7.9*	51.9±10.0*	54.2±7.2*	50.2±9.8*
Stage 3–4	5.8±6.5	18.3±5.7*	16.8±6.1*	16.3±6.6*	15.8±6.6*
REM %	9.0±3.8	21.4±6.1*	21.6±9.0*	20.4±6.3*	22.7±6.6*

Data are presented as mean±sd

CPAP: continuous positive airway pressure

NREM: nonrapid eye movement; REM: rapid eye movement

*: $p < 0.05$ versus diagnostic night

Arousal

Figure 2 shows the individual results for total arousal index. No significant differences were found between the automatic CPAP devices compared to fixed CPAP. Figure 3 gives an overview of the arousals separated into respiratory and nonrespiratory arousals, as well as arousal after pressure elevation. The number of respiratory arousals with fixed CPAP was significantly lower than with the AutoSet and Virtuoso devices. No significant difference was seen between the AutoSet and the Horizon. With the Virtuoso, the number of respiratory arousals was significantly higher than with the Horizon and fixed CPAP.

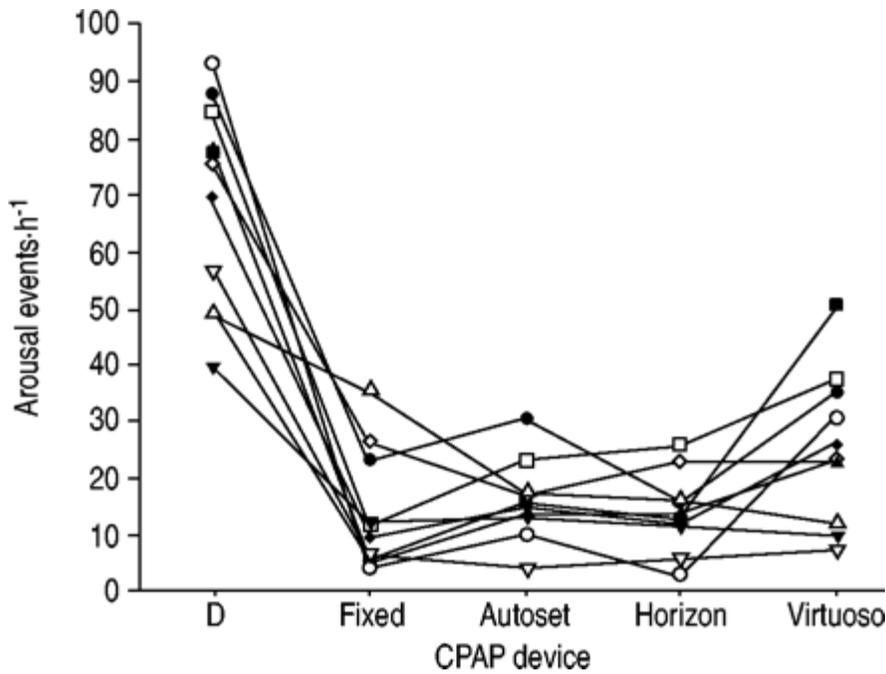


Fig. 2.— Individual results for total arousal index during the diagnostic (D) and treatment nights using various continuous positive airway pressure (CPAP) devices.

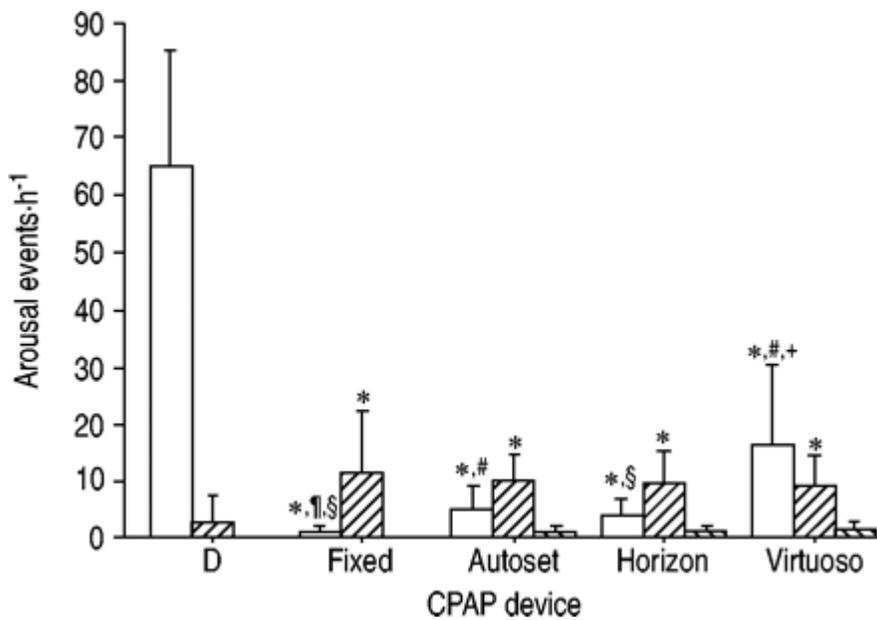


Fig. 3.— Arousal caused by respiratory events (□; apneas, hypopneas and snoring), as well as non-respiratory events (■) or pressure elevation (▨), during the diagnostic (D) and treatment nights using various continuous positive airway pressure (CPAP) devices. Data are presented as mean±sd. *: $p < 0.05$ versus diagnostic night; #: $p < 0.05$ versus fixed CPAP; \$: $p < 0.05$ versus AutoSet; +: $p < 0.05$ versus Horizon; ,: $p < 0.05$ versus Virtuoso.

The arousals seen after an increase in pressure by automatic CPAP devices ranged 0.8–1.3 events ·h⁻¹ and were not significantly different between the automatic CPAP devices. In addition, no significant difference was found in the number of non-respiratory arousals between the 4 treatment nights.

Oxygen saturation

The minimal and mean S_{a,O_2} during the treatment nights are shown in table 2. The differences found in minimal and mean S_{a,O_2} and the percentage of TST spent with an S_{a,O_2} of <90% did not differ significantly between automatic CPAP devices compared to fixed CPAP.

Table 2— Arterial oxygen saturation (S_{a,O_2}) and time spent at an S_{a,O_2} of <90% during treatment nights

	Fixed CPAP	Automatic CPAP		
		Virtuoso	Horizon	AutoSet
Mean S_{a,O_2} %	95.2±1.6	95.8±1.3	95.5±1.0	94.7±3.1
Minimum S_{a,O_2} %	84.9±3.6	84.5±5.1	86.4±2.6	81.5±6.5
TST at <90% S_{a,O_2} %	0.59±0.74	0.98±1.70	0.33±0.36	9.29±26.63

Data are presented as mean±sd

CPAP: continuous positive airway pressure

TST: total sleep time

Mask pressure

Figure 4 shows the mean mask pressure with fixed CPAP, as well as the mean and maximal pressures with the automatic CPAP devices. The mean pressure with fixed CPAP was 9.9 ± 1.8 cmH₂O, and was significantly lower with the AutoSet (7.3 ± 1.6 cmH₂O) and Virtuoso (6.5 ± 2.3 cmH₂O) devices. No significant difference was found for the Horizon (8.5 ± 2.8 cmH₂O) compared to fixed CPAP. The mean pressures did not differ significantly between the three automatic CPAP devices.

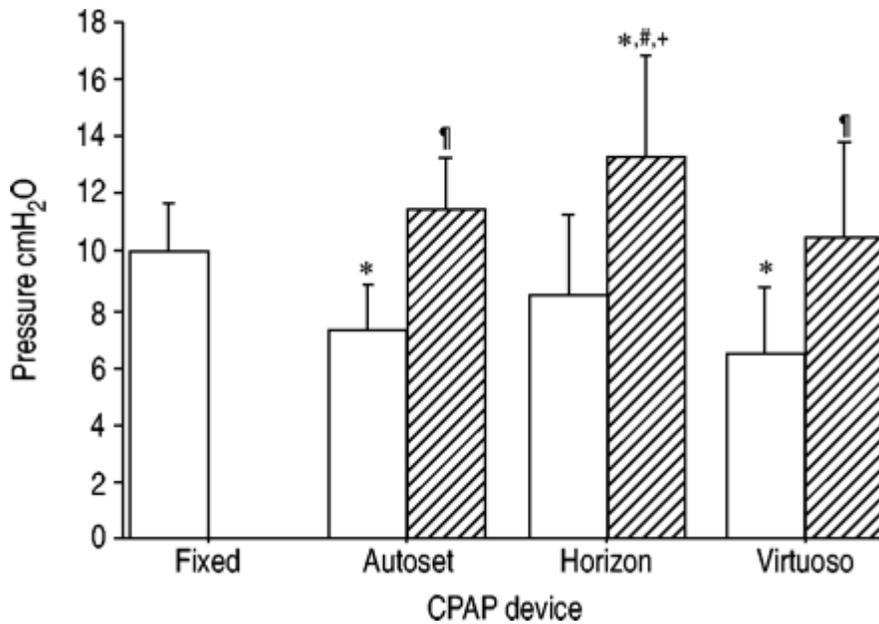


Fig. 4.— Mean (□) and maximum (▨) pressure with the various continuous positive airway pressure (CPAP) devices. Data are presented as mean±sd. *: $p < 0.05$ versus fixed CPAP; #: $p < 0.05$ versus AutoSet; †: $p < 0.05$ versus Horizon; +: $p < 0.05$ versus Virtuoso.

Figure 4 also shows that, with automatic CPAP devices, higher maximal pressures were applied compared to fixed CPAP (11.4 ± 1.9 , 13.3 ± 3.5 and 10.5 ± 3.3 cmH₂O for the AutoSet, Horizon and Virtuoso devices, respectively). Compared to fixed CPAP, this difference was not significant for the AutoSet and Virtuoso, but maximum pressure with the Horizon was significantly higher than with fixed CPAP and the AutoSet and Virtuoso. The percentage of TST spent with a pressure higher than with fixed CPAP did not differ significantly between the automatic CPAP devices (table 3).

Table 3— Time spent with a pressure (P) higher than with fixed continuous positive airway pressure (CPAP)

	AutoSet	Horizon	Virtuoso
TST at $P >$ fixed CPAP %	22.8±33.8	38.6±32.9	6.1±12.3

Data are presented as mean±sd

TST: total sleep time

Discussion

The automatic CPAP devices tested in the present study significantly reduced the AHI of patients with moderate-to-severe obstructive sleep apnoea. Compared to fixed CPAP, the AHI was significantly higher with all automatic nCPAP devices. Optimal treatment, with an AHI of <5 events \cdot h $^{-1}$, generally accepted as normal [18](#), was seen in all patients by use of fixed CPAP and in 10 of the 12 patients with the AutoSet and Horizon devices, but in only six of the 12 patients with the Virtuoso. With the automatic CPAP devices, S_{a,O_2} , arousal index and sleep structure were substantially improved in a way that was similar to that with fixed CPAP. The mean CPAP pressure of the automatic CPAP devices was 1.4–3.5 cmH $_2$ O lower than with fixed CPAP, which was significant for the AutoSet and Virtuoso. However, with all autotitrating CPAP devices, the maximum pressure applied throughout the night was 0.6–3.4 cmH $_2$ O higher than with fixed CPAP.

A prospective controlled randomized crossover design was chosen for the present study. All patients were studied polysomnographically over six consecutive nights. Although all of the patients underwent a diagnostic study on the first night and manual titration of fixed CPAP on the following night, the order in which the three automatic CPAP devices and fixed CPAP were applied over the subsequent 4 nights was randomized and balanced. Thus any sequence effect was avoided. In contrast to many previous studies, the effect of automatic CPAP devices was compared with effective fixed CPAP, whereas several previous studies compared automatic CPAP treatment alone with the diagnostic night [19](#) or with the results of the pressure determination night for fixed nCPAP [13](#), [20](#).

The present study confirms the significant reduction in AHI obtained with individual automatic CPAP devices [11](#), [14](#), [15](#), [21–26](#). In addition and for the first time, it provides comparative data demonstrating substantial differences in the effectiveness of different automatic CPAP devices and fixed nCPAP.

The greatest AHI reduction of $>98\%$ was achieved with fixed CPAP. In two previous studies, the results with automatic CPAP were better than those with fixed CPAP [12](#), [13](#), most probably due to the fact that, unlike in the present study, no attempt was made by these authors to eliminate snoring as a symptom of persisting partial upper airway obstruction. A further cause of the relatively poor results with fixed CPAP in these studies may be that the AHI of the manual titration night, with longer periods of ineffective fixed nCPAP, was compared with the results of automatic CPAP. Scharf *et al.* [27](#), using a study design similar to that in the present study, also found a lower AHI with fixed CPAP compared to automatic CPAP (the Horizon), although the results of the two treatment modalities did not differ significantly.

Although all three automatic devices studied significantly reduced the AHI, substantial differences in effectiveness were shown. The AutoSet as well as the Horizon device reduced the AHI by $>90\%$ and thus came close to the optimal result achieved with fixed nCPAP. Although the AHI with both devices was significantly higher than with fixed CPAP, these differences were small and most probably clinically irrelevant. With the Virtuoso, mean AHI was significantly reduced by $>80\%$ compared to the diagnostic night; however, the AHI remained at >10 events \cdot h $^{-1}$ in six of the 12 patients studied and mean AHI with the Virtuoso was substantially higher than with fixed CPAP. Since the Virtuoso does not utilize a pneumotachograph, it does not reliably detect the obstructive apneas with complete upper airway occlusion that occur suddenly without previous snoring in some patients. Conversely, the system reacts adequately with an increase in pressure to partial airway obstruction such as obstructive hypopneas and snoring. Sharma *et al.* [20](#) demonstrated a reduction in AHI from 50.8 to 6.1 events \cdot h $^{-1}$ with the Virtuoso, but to ≈ 3 events \cdot h $^{-1}$ with fixed CPAP. As in the present study, it was observed that the Virtuoso did not increase pressure despite upper airway obstruction in seven of 20 patients.

Normalization of sleep stages was observed during the treatment nights. The longest duration of slow-wave sleep was found with fixed CPAP, most probably caused by the largest reduction in AHI and respiratory arousal index with this device.

Compared to the other three devices, treatment with the Virtuoso led to a substantially higher total arousal index, which can be attributed to persisting breathing disturbances. As expected, the number of nonrespiratory arousals did not differ significantly between fixed CPAP and any of the three automatic nCPAP machines in the present study, and they even occurred less frequently than in a study in healthy subjects [28](#). Arousal after pressure elevation during automatic CPAP accounted for <7% of all arousals. Thus, arousals caused by pressure increase is not a relevant problem in the devices tested.

The mean treatment pressure of all of the automatic CPAP devices was lower than that used for fixed CPAP. With the AutoSet and Horizon, the mean pressure was lower (27% and 14%, respectively) than with fixed CPAP. Treatment with these two devices was slightly less effective than with fixed CPAP. The lowest mean mask pressure was applied by the Virtuoso (34% lower). However, the Virtuoso failed to increase pressure in reaction to breathing disorders, leading to the highest AHI and arousals and the lowest S_{a,O_2} with treatment.

The maximum pressure applied during automatic CPAP treatment clearly exceeded the pressure used for fixed CPAP, and patients spent up to 38% (the Horizon) of TST with a pressure that was higher than with fixed CPAP; thus, unnecessarily high mask pressure may be applied by autotitrating devices.

Based on the present study, it cannot be concluded that automatic CPAP is as effective in an unattended situation in the patient's home. Several observations were made of the automatic CPAP machines erroneously increasing pressure due to mask leaks, and, in three patients, this was the reason for withdrawal of their consent to continue the study. Therefore, unattended automatic nCPAP without an upper pressure limit may deter patients from nCPAP therapy. Furthermore, the only aspect of the initiation of CPAP therapy that was dealt with by the automatic device was pressure determination. All of the other aspects, such as mask adaptation, prevention or removal of leak, and patient support, were performed by experienced technicians.

The present study demonstrates substantial differences in the performance of automatic nCPAP devices in the clinical setting. In addition to bench testing, clinical testing of the different devices, as performed here, is essential for the evaluation of the performance and efficacy of automatic CPAP in routine use. Devices that do not achieve a reduction in breathing disorders similar to those obtained with fixed nCPAP should not be used. From the present study, the current authors have come to the conclusion that fixed nCPAP should be used in the first line of treatment. If patients report discomfort with fixed nCPAP, automatic CPAP with devices that lead to a prevention of breathing disorders comparable to those obtained with fixed nCPAP may be a valuable additional treatment option.

It is concluded that two of the three automatic continuous positive airway pressure devices tested effectively treat patients with uncomplicated obstructive sleep apnoea in the sleep laboratory and provide treatment results that are comparable to those obtained with fixed continuous positive airway pressure, the standard treatment at present. The present study also demonstrates that not all autotitrating devices are equally effective. The Virtuoso device did not work properly in 50% of the patients, and, as a consequence, is no longer commercially available in Germany.

References

1. Sullivan C, Issa F, Berthon Jones M, Eves L. Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. *Lancet* 1981;1:862–865. [\[ISI\]](#) [\[Medline\]](#) [\[Order article via Infotrieve\]](#)
2. Anon. American Thoracic Society Official Statement. Indications and standards for use of nasal continuous positive airway pressure (CPAP) in sleep apnea syndrome. *Am J Respir Crit Care Med* 1994;50:1738–1745.
3. Jenkinson C, Davies RJ, Mullins R, Stradling JR. Comparison of therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: a randomized prospective parallel trial. *Lancet* 1999;353:2100–2105. [\[CrossRef\]](#) [\[ISI\]](#) [\[Medline\]](#) [\[Order article via Infotrieve\]](#)
4. Pepperell JC, Ramdassingh-Dow S, Crosthwaite N, *et al.* Ambulatory blood pressure after therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: a randomized parallel trial. *Lancet* 2002;360:204–210.
5. Becker HF, Jerrentrup A, Ploch T, *et al.* Effect of nasal continuous positive airway pressure treatment on blood pressure in patients with obstructive sleep apnea. *Circulation* 2003;107:68–73. [\[CrossRef\]](#) [\[ISI\]](#) [\[Medline\]](#) [\[Order article via Infotrieve\]](#)
6. Deegan PC, McNicholas WT. Pathophysiology of obstructive sleep apnoea. *Eur Respir J* 1995;8:1161–1178. [\[Abstract\]](#)
7. Neill AM, Angus SM, Sajkov D, McEvoy RD. Effects of sleep posture on upper airway stability in patients with obstructive sleep apnea. *Am J Respir Crit Care Med* 1997;155:199–204. [\[Abstract\]](#)
8. Oksenberg A, Silverberg DS, Arons E, Radwan H. The sleep supine position has a major effect on optimal nasal continuous positive airway pressure: relationship with rapid eye movements and non-rapid eye movements sleep, body mass index, respiratory disturbance index, and age. *Chest* 1999;116:1000–1006. [\[Abstract/Free Full Text\]](#)
9. Teschler H, Berthon-Jones M, Wessendorf T, Meyer HJ, Konietzko N. Influence of moderate alcohol consumption on obstructive sleep apnoea with and without AutoSet nasal CPAP therapy. *Eur Respir J* 1996;9:2371–2377. [\[Abstract\]](#)
10. Pepin J, Nadjafizadeh H, Benkheira N, Levy P. A self-adjusted CPAP device for OSA using snoring detection and pressure changes: clinical validity. *Am J Respir Crit Care Med* 1995;A534.
11. Lofaso F, Lorino A, Duizabo D, *et al.* Evaluation of an auto-nCPAP device based on snoring detection. *Eur Respir J* 1996;9:1795–1800. [\[Abstract\]](#)
12. Teschler H, Berthon Jones M, Thompson A, Henkel A, Henry J, Konietzko N. Automated continuous positive airway pressure titration for obstructive sleep apnea syndrome. *Am J Respir Crit Care Med* 1996;154:734–740. [\[Abstract\]](#)
13. Lloberes P, Ballester E, Montserrat JM, *et al.* Comparison of manual and automatic CPAP titration in patients with sleep apnea/hypopnea syndrome. *Am J Respir Crit Care Med* 1996;154:1755–1758. [\[Abstract\]](#)

14. Stradling J, Barbour C, Pitson D, Davis R. Automatic nasal continuous positive airway pressure titration in the laboratory: patient outcomes. *Thorax* 1997;52:72–75. [\[Abstract\]](#)
15. Meurice JC, Marc I, Series F. Efficacy of auto-CPAP in the treatment of obstructive sleep apnea/hypopnea syndrome. *Am J Respir Crit Care Med* 1996;153:794–798. [\[Abstract\]](#)
16. Rechtschaffen A, Kales A, A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects. NIH publication No. 204. Bethesda, MD, National Institutes of Health, 1968.
17. American Sleep Disorders Association. EEG arousals: scoring rules and examples: a preliminary report from the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association. *Sleep* 1992;15:173–184. [\[Medline\]](#) [\[Order article via Infotrieve\]](#)
18. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. *N Engl J Med* 1993;328:1230–1235. [\[Abstract/Free Full Text\]](#)
19. Berthon-Jones M, Lawrence S, Sullivan CE, Grunstein R. Nasal continuous positive airway treatment: current realities and future. *Sleep* 1996;19: Suppl. 9, S131–S135. [\[ISI\]\[Medline\]](#) [\[Order article via Infotrieve\]](#)
20. Sharma S, Wall S, Poullot Z, Peters M, Neufeld H, Kryger M. Treatment of obstructive sleep apnea with a self-titrating continuous positive airway pressure (CPAP) system. *Sleep* 1996;19:497–501. [\[ISI\]\[Medline\]](#) [\[Order article via Infotrieve\]](#)
21. Behbehani K, Yen F, Lucas E, Burk J. A sleep laboratory evaluation of an automatic positive airway pressure system for treatment of obstructive sleep apnea. *Sleep* 1998;21:485–491. [\[ISI\]\[Medline\]](#) [\[Order article via Infotrieve\]](#)
22. Berthon Jones M. Feasibility of a self-setting CPAP machine. *Sleep* 1993;16:120–123.
23. Fleetham J, Burt H, Anderson B. Assessment of the efficacy of automatic nasal CPAP therapy in the treatment of obstructive sleep apnea. *Am J Respir Crit Care Med* 1996;A872.
24. Montserrat JM, Lloberes P, Ballester E, *et al.* Comparison of manual and automatic CPAP titration in patients with sleep apnea/hypopnea syndrome (SAHS). *Am J Respir Crit Care Med* 1996;A872.
25. Robert D, Bourdon G, Langevin B, Leger P, Guez A. Usefulness and efficacy of an auto adjustable CPAP machine in treatment of OSAS. *Am Rev Respir Dis* 1993;147:A680.
26. Series F. Auto CPAP in the treatment of sleep apnea hypopnea syndrome. *Sleep* 1996;19:281–283.
27. Scharf MB, Brannen DE, McDannold MD, Berkowitz DV. Computerized adjustable *versus* fixed NCPAP treatment of obstructive sleep apnea. *Sleep* 1996;19:491–496. [\[ISI\]\[Medline\]](#) [\[Order article via Infotrieve\]](#)
28. Mathur R, Douglas NJ. Frequency of EEG arousal from nocturnal sleep in normal subjects. *Sleep* 1995;18:330–333. [\[ISI\]\[Medline\]](#) [\[Order article via Infotrieve\]](#)

Accuracy of an Unattended Home CPAP Titration in the Treatment of Obstructive Sleep Apnea F. SÉRIÈS

Unité de Recherche, Centre de Pneumologie, Hôpital et Université Laval, Québec, Canada

Abstract

Treatment of sleep apnea-hypopnea syndrome (SAHS) by fixed continuous positive airway pressure (CPAP) requires an in-laboratory titration procedure to determine the effective pressure level (Peff). We recently reported that one auto-CPAP machine can be used without titration study allowing Peff determination. The aim of this study was to evaluate the accuracy of an auto CPAP trial at home. A 1- or 2-wk automatic CPAP trial was done at home in 40 patients by estimating the reference pressure (Pref) to be set and a Pref + 3 cm H₂O/ -4 cm H₂O pressure interval. Peff was then determined according to the percentage of CPAP time that was spent ≤ Pref. This Peff value was set on a fixed CPAP machine for two additional weeks and a control sleep study was done. The pressure setting on fixed CPAP had to be increased by 1 ± 1 cm H₂O (mean ± SD) above estimated Pref. Sleep improved with fixed CPAP, with a normalization of the apnea + hypopnea index (AHI) in 38 of 40 and resumption of diurnal hypersomnolence. CPAP compliance remained excellent (CPAP use: 6.1 ± 1.7 h/night) after 6.5 ± 2.8 mo of CPAP treatment. These results indicate that auto-CPAP therapy represents a new useful and accurate way to identify conventional CPAP setting outside hospital and sleep laboratories.

Introduction

Obstructive sleep apnea-hypopnea syndrome (SAHS) is highly prevalent in the middle-aged active population (1). It significantly interferes with quality of life (2) and is associated with an increase in morbidity and mortality (3). It is currently admitted that nasal continuous positive airway pressure (nCPAP) represents one of the most effective treatments for SAHS. The determination of the effective pressure level (Peff) is realized during a titration sleep study that is routinely achieved during in-laboratory sleep studies and consists of the continuous acquisition of electrophysiologic, ventilatory, and respiratory efforts and transcutaneous SaO₂ characteristics. Peff corresponds to the pressure level that abolishes obstructive apnea and hypopnea and sleep fragmentation related to flow-limited breaths in every sleep stage and body position. In expert hands, this procedure can also be realized automatically outside sleep laboratories during in-hospital recordings using auto-titrating continuous positive airway pressure (CPAP) machines that allow a continuous self-adjustment of the positive pressure level to the required needs (4).

Even if obstructive breathing disorders are theoretically abolished at the end of the CPAP titration night, this procedure only provides useful information on the Peff level during one single night in a dedicated environment. However, other factors such as body and neck or mandibular position, weight changes, and nasal obstruction may further contribute to modify Peff (5). One way to bypass these intra-night and night-to-night changes in Peff is to use automatic CPAP machines at home (8, 9).

However, up to now the identification of patients who will benefit from these new devices compared with conventional CPAP remains unknown, making constant CPAP the standard treatment mode in the majority of patients with SAHS. However, considering that sleep conditions during the titration sleep study may significantly differ from those encountered at home and do not take into account the night-to-night variability in the Peff level, an ideal CPAP titration procedure should be based on a CPAP titration trial conducted at home during several nights.

We have recently reported that one of the first-generation auto-CPAP machines (Morphée Plus/Cloudnine, Pierre Médical/Nelcor Puritan Bennett, Minneapolis, MN) can be used without titration sleep study by estimating the pressure around which the machine is constantly tuning to identify the minimal effective pressure level (reference pressure: [Pref]) (10). In these circumstances, the ability of the device to decrease the positive pressure level below Pref decreases with increasing Pref. underestimation, with a negative relationship between the percentage of CPAP time \leq Pref. and the difference between Peff and Pref. According to this relationship, one could determine Peff by measuring the percentage of CPAP time spent below Pref for a given estimated Pref value. We reasoned that the aforementioned relationship could be used to determine the adequate setting for fixed CPAP therapy after an automatic CPAP trial at home for several days without need of an in-hospital titration sleep study. We therefore designed a study to evaluate the accuracy of such a procedure to determine the positive pressure level setting for fixed CPAP therapy using the Morphée Plus/Cloudnine machine at home during 1 or 2 wk in newly diagnosed, untreated patients with SAHS.

METHODS

Subjects

Forty-two untreated consecutive patients with SAHS (age range, 37 to 66 yr) who were willing to undergo CPAP therapy as a treatment for their sleep disorder were included in the study. The only inclusion criterion was that they were living within 100 km from the hospital. Each patient had a baseline polysomnographic study to confirm clinical diagnosis (*see DATA AND STATISTICAL ANALYSIS for details*). The review board of our institution accepted the protocol and an informed consent form was obtained from each participating subject.

Protocol

A subjective assessment of diurnal hypersomnolence was done using the Epworth sleepiness score (11). Figure 1 illustrates our study design. After the baseline polysomnographic study, Pref was estimated according to the formula: $\text{Pref} = 0.193 * \text{body mass index (BMI)} + 0.077 * \text{neck circumference} + 0.020 * \text{apnea + hypopnea index (AHI)} - 0.611$. This formula differs slightly from that we previously used (9) but was prospectively validated in 50 consecutive patients previously investigated in our laboratory using our standard recording and interpretation methods. To evaluate the effect of the home titration duration on the accuracy of this titration procedure, patients were randomly allocated to a 1- or 2-wk home automatic CPAP trial, the two groups being paired (± 1 cm H₂O) for the estimated value of Pref. The automatic CPAP setting was then fixed to +3 cm H₂O above and -4 cm H₂O below the estimated Pref. CPAP installation, determination of the adequate size of nasal mask, and demonstration of the procedures to operate the machine and install the mask were made by a home care company (Vital Aire, Québec, Canada). In 17 patients, a heated humidifier was prescribed within the first days of treatment owing to nasal congestion and stuffiness secondary to CPAP use. In these patients, the pressure setting was adjusted so that the mask pressure corresponded to the prescribed pressure value when using the humidifier circuit.

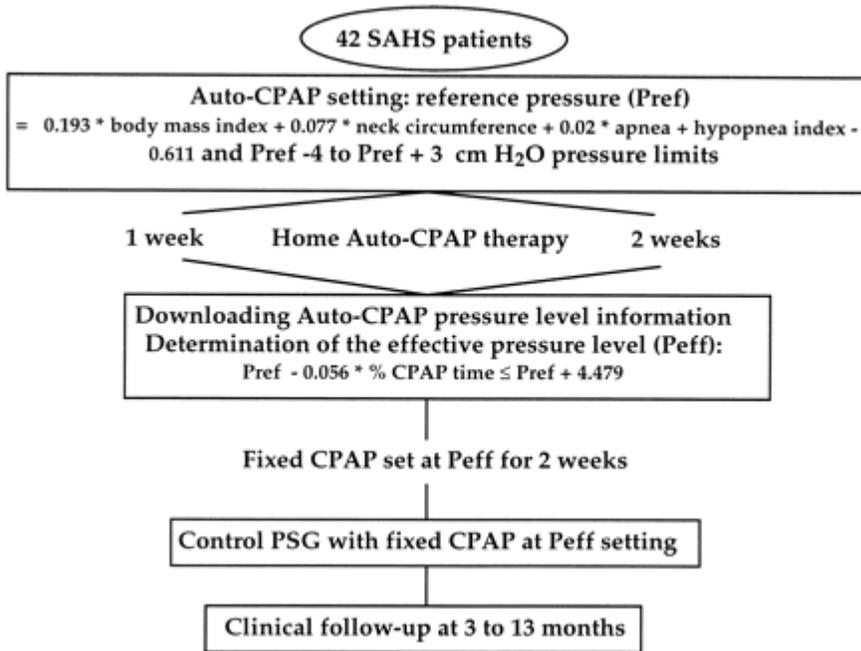


Figure 1. Schematic representation of our study design.

At the end of the automatic CPAP trial, patients brought their machine back to the home care company, and a print-out of the night-by-night characteristics of positive pressure delivery was obtained. This chart provides the time during which a positive pressure was applied and the percentage of this time spent at the different pressure levels. According to these data, the investigator (F.S.) determined the percentage of CPAP time that was spent at or below Pref. Using the previously validated relationship that exists between the time spent at or below Pref and the difference between Pref and estimated Peff, it is possible to determine Peff according to the formula $P_{eff} = P_{ref} - 0.056 * \% \text{ CPAP time} \leq P_{ref} + 4.479$ (Figure 2). This formula was validated in 21 subjects, nine being added to our previously published results (9). This new pressure level was set on a conventional fixed CPAP machine for two additional weeks and a control sleep study was done while using their CPAP machine at the end of the study period. A new assessment of diurnal sleepiness with the Epworth sleepiness score was obtained.

% CPAP time \leq Pref

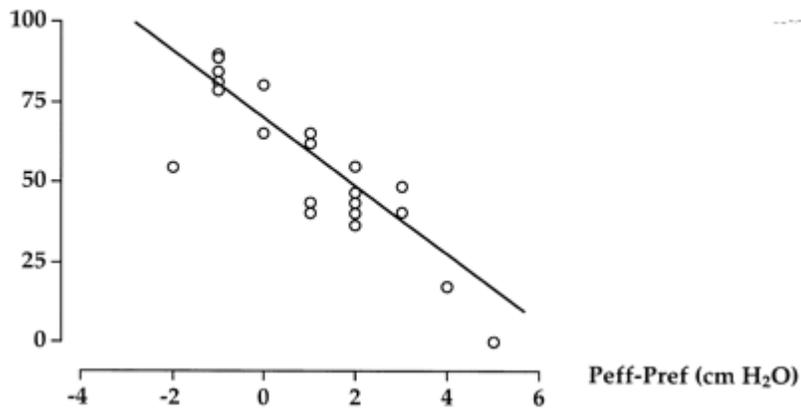


Figure 2. Correlation between the percentage of positive pressure time that is spent at or below the Pref and the difference between the measured Peff and Pref. There is a significant negative relationship between these variables.

A follow-up visit was obtained after 3 to 12 mo of CPAP therapy to determine the number of patients who were still using the machine and to estimate CPAP observance by measuring the difference in time counter hours from the beginning of treatment.

Data and Statistical Analysis

Sleep (electroencephalogram [EEG], electro-oculogram [EOG], submental electromyogram [EMG], anterior tibialis EMG) and respiratory variables (nasal flow, thoracoabdominal movements, transcutaneous SaO₂, breathing noise) obtained during the baseline and control CPAP polysomnographic studies were analyzed manually according to standard criteria (12). For the CPAP sleep study, breathing disorders were scored on the instantaneous flow tracing provided by a pneumotachograph (Hamilton Medical flow sensor, Via Nova, Switzerland) connected to the nasal mask. Comparison of the two groups' characteristics at baseline values were compared by an unpaired *t* test. To compare the changes obtained in the 1- and 2-wk auto-CPAP groups, a repeated analysis of covariance with baseline data as covariate was performed. The α level was set at 0.05. Data were analyzed by using the SAS statistical package (SAS Institute, Inc., Cary, NC).

Results

The CPAP trial was interrupted during the home auto-CPAP trial in two subjects owing to incapacity to wear the mask (claustrophobia) in one, and to the wife's complaints concerning CPAP treatment requirements in the other. We will therefore present the data obtained in 40 subjects. Characteristics of the patients are reported in Table 1. No difference was found in any of these variables between the two groups. No subject experienced any difficulty in initiating CPAP treatment. Treatment compliance was high during the home titration phase as assessed by the number of hours the machine was used (6.6 ± 1.5 h/night) and the number of hours a positive pressure was applied (5.9 ± 1.4 h/night) during this study period. No significant difference in these parameters was found between the 1- and 2-wk auto-CPAP titration groups. The percentage of CPAP time that was spent below estimated Pref measured at the end of this home titration phase was $63.8 \pm 13.0\%$. The number of patients corresponding to each amount of pressure change calculated according to the previously described relationship between the percentage of CPAP time and the difference between estimated Pref and the constant pressure level to be set is represented in Figure 3. For the whole group, the mean calculated

pressure setting was 1 ± 1 cm H₂O higher than estimated Pref. This new pressure level was set on a fixed CPAP machine for two additional weeks. There was no dropout during this second part of the study.

TABLE 1
CHARACTERISTICS OF THE STUDY POPULATION*

	One-week Group	Two-week Group
Neck circumference, cm	42.5 ± 3.4	41.5 ± 3.6
BMI, kg/m ²	33.9 ± 7.7	32.0 ± 6.7
AHI, n/h	42.7 ± 23.7	48.2 ± 27.8
% Total sleep time < 90% SaO ₂	7.4 ± 10.4	7.3 ± 11.0
Estimated reference pressure, cm H ₂ O	10.0 ± 1.7	9.7 ± 1.7

Definition of abbreviations: AHI = apnea + hypopnea index; BMI = body mass index.

* Values are expressed as mean ± SD.

N

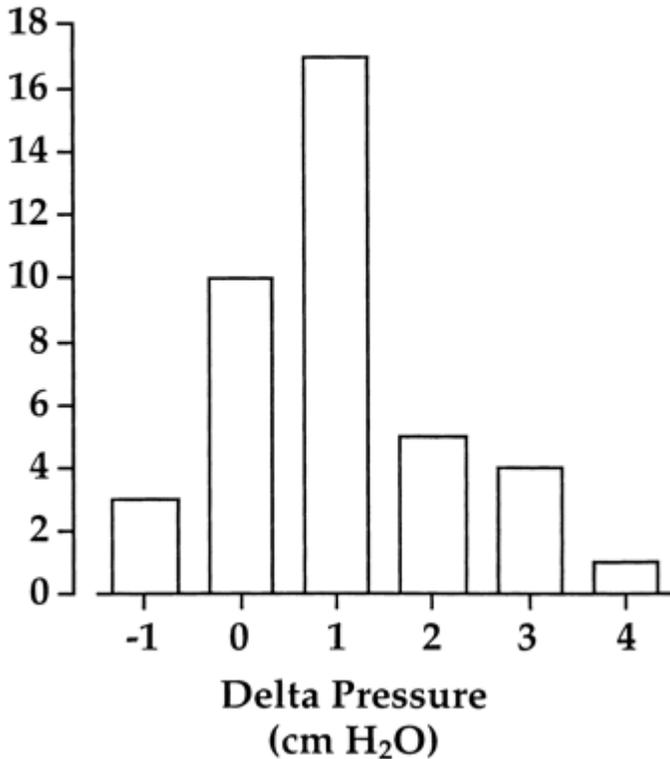


Figure 3. Repartition of the patients according to the difference between estimated Pref and calculated Peff measured at the end of auto-CPAP trial.

The changes in sleep and respiratory variables and in subjective daytime sleepiness are described in Table 2. A significant improvement was observed in each of these parameters (sleep architecture, sleep fragmentation, AHI, nocturnal desaturation). The AHI normalized ($< 10/h$) in all but two subjects. In the first one, the calculated pressure setting was 10 cm H₂O. His AHI was 15.2/h, apneic and hypopneic events being essentially central in nature. We asked this patient to interrupt CPAP therapy for 1 wk to realize a conventional sleep study. Peff level measured during this titration night was 9 cm H₂O but central events were even observed at this pressure level, which was the optimal one to abolish sleep-induced obstructive breathing disorders. In the other subject, the AHI was 35/h (obstructive events). It was retrospectively found that his auto-CPAP machine was unfortunately damaged during the first home CPAP trial, and that this interfered with the ability of the compressor to adequately adapt the positive pressure level. The arousal index with CPAP was $15.9 \pm 6.7/h$ and the frequency of respiratory-related arousals was normal ($< 15/h$) in all patients but the two subjects whose AHI remained abnormal ($9.4 \pm 9.4 n/h$). The Epworth sleepiness score significantly improved (Table 2), the score going down to normal values (< 10) in 33 subjects. In the seven others, three had sleep fragmentation because of periodic leg movements, two because of persisting sleep apneas, the sleep study being normal in the other two.

TABLE 2
 MEAN ± SD VALUES OF BASELINE AND CONTROL CPAP SLEEP STUDIES AND MEAN DIFFERENCE BETWEEN THE TWO STUDIES*

AHI, n/h

Stage I-II, % total sleep time

Stage III-IV, % total sleep time

Stage REM, % total sleep time

Arousal index, n/h

% total sleep time > 90% SaO₂

Epworth sleepiness score

Definition of abbreviations: REM = rapid eye movement.

* The control CPAP sleep study was done with the fixed CPAP level set at the positive pressure level that was determined during the auto-CPAP trial.

Patients were seen at follow-up after 6.5 ± 2.8 mo of CPAP treatment using the pressure setting determined during the auto-CPAP trial. Thirty-six of them were still on CPAP (two stopped CPAP therapy because the machine was too cumbersome, one because of pressure discomfort, and one owing to financial considerations). Symptom relief was still present in each of them. The number of hours the machine was turned on from the beginning of fixed CPAP therapy was 6.1 ± 1.7 h/night.

DISCUSSION

Recent data from the literature demonstrate that auto-CPAP therapy is as effective as conventional CPAP (8, 9, 15). However, the benefits of this new mode of CPAP therapy are not clearly defined because no comparison of medium- or long-term efficacy of fixed and auto-CPAP on sleep and respiratory variables, treatment compliance, improvement in objective daytime sleepiness, and risk factors has been done so far. Therefore, today fixed CPAP still remains the reference for home

treatment for obstructive sleep apnea. Auto-CPAP machines may have another application, that is, to automatically determine the Peff level outside sleep laboratories. The accuracy and efficacy of this strategy depend on the machine that is used but have been shown to be generally good in experts' hands (18, 19). However, auto-CPAP titration requires review of recording to verify the adequacy of automatic pressure changes, to delete the undesirable recording periods (e.g., with mask leaks or mouth breathing), and to analyze the positive pressure trend to determine the effective pressure level. Such expertise is not required in the algorithm of effective pressure determination that is described in the present study. In fact, determining Peff only requires (1) estimating the reference pressure to be set on the Morphée Plus/Cloudnine machine (using the formula with BMI, neck circumference, and AHI values); (2) measuring the percentage of CPAP time that was spent below Pref during the home CPAP titration period; and (3) correcting for Pref estimate according to the percent CPAP time \leq Pref / Peff-Pref relationship. These different steps could be done automatically by the auto-CPAP machine with a dedicated program.

Besides the efficacy of this titration procedure after 2 wk of fixed CPAP therapy, the present results provide very important information on the feasibility of CPAP treatment without in-hospital recording in patients whose first experience with this treatment was done at home without any on-line recording or attending by specialized personnel. Furthermore, our results demonstrate that this strategy does not alter treatment compliance during the initial titration period, neither during conventional CPAP therapy for both short- and long-term treatment periods, because CPAP therapy was accepted by 86% of patients at the control visit. The proposed home titration procedure is simple, requiring only good training of patients by the home care company; according to this strategy, a simple computer analysis of positive pressure changes during the trial allows a determination of the fixed pressure level to be set at home. From our data, a 1-wk trial is as efficient as a 2-wk period to determine Peff.

As previously mentioned, Peff corresponds to the pressure level that abolishes obstructive respiratory events and sleep fragmentation related to flow-limited breaths. It could be argued that the home titration procedure that we propose could be imperfect because the apparatus that we used only detects and corrects apneic and hypopneic events but does not identify flow-limited breaths. This potential drawback is compensated by the relationship that is used to calculate Peff according to the percentage of positive pressure time spent \leq Pref because in the patients in whom the formula was validated, Peff was determined during a conventional titration sleep study and therefore met the ideal Peff measurements criteria.

It can be asked if our procedure to determine Peff could be improved by further tuning of our formula to estimate Pref (i.e., increase Pref by 1 cm H₂O, which is the average difference between Peff and Pref in our study population). We believe that this will not bypass the need for an auto-CPAP trial because improving Pref accuracy (i.e., mean pressure change equal to zero in a given patient population) would mean that an equal number of subjects need an increase or a decrease in their pressure setting. Therefore, Peff determination will still have to be checked by the home auto-CPAP trial.

The results of this study should have important practical repercussions on the way CPAP treatment is initiated in obstructive sleep apnea patients. A short auto-CPAP trial at home for 1 or 2 wk could be proposed by home care services before setting fixed CPAP therapy. However, it is particularly important to be aware that the algorithm of Peff determination that we have validated cannot be applied to other auto-CPAP devices that have different pressure limits and pressure responses criteria that should obviously modify the relationship that is used to determine Peff. Another important clinical issue arising from our results is that auto-CPAP titration at home must be accompanied by a strict follow-up of these patients. In those whose clinical response is not optimal, a control polysomnographic study with the determined pressure setting should be done to distinguish between

inadequate pressure setting and other causes of persisting hypersomnolence (periodic leg movements, idiopathic).

We conclude that auto-CPAP therapy represents a new useful and accurate way to identify conventional CPAP setting outside hospital and sleep laboratories, and that CPAP titration procedures should be realized in patients in whom this strategy had failed.

References

1. Young, T., M. Palta, J. Dempsey, J. Skatrud, S. Weber, and S. Badr. 1993. The occurrence of sleep-disordered breathing among middle-aged adults. *N. Engl. J. Med.* 328: 1230-1235 [[Abstract/Free Full Text](#)].
2. Toussignat, P., M. Cosio, R. D. Levy, and P. A. Groome. 1994. Quality of life years added by treatment of obstructive sleep apnea. *Sleep* 17: 52-60 [[Medline](#)].
3. He, J., M. H. Kryger, F. J. Zorick, W. Conway, and T. Roth. 1988. Mortality and apnea index in obstructive sleep apnea: experience in 385 male patients. *Chest* 94: 9-14 [[Abstract/Free Full Text](#)].
4. Stradling, J. R., C. Barbour, and R. J. O. Davies. 1997. Automatic nasal continuous positive airway pressure titration in the laboratory: patient outcomes. *Thorax* 52: 72-75 [[Abstract](#)].
5. Sériès, F., I. Marc, Y. Cormier, and J. La Forge. 1994. Changes in the required levels of nasal continuous positive airway pressure in the course of treatment of obstructive sleep apnea. *Eur. Respir. J.* 7: 1776-1781 [[Abstract](#)].
6. Meurice, J. C., I. Marc, G. Carrier, and F. Sériès. 1996. Effects of mouth opening on upper airway collapsibility in normal sleeping subjects. *Am. J. Respir. Crit. Care Med.* 153: 255-259 [[Abstract](#)].
7. Lafond, C., and F. Sériès. 1998. Influence of nasal obstruction on auto-CPAP behaviour during sleep in sleep apnoea/hypopnoea syndrome. *Thorax* 53: 780-783 [[Abstract/Free Full Text](#)].
8. Teschler, H., and M. Berthon-Jones. 1998. Intelligent CPAP systems: clinical experience. *Thorax* 53: S49-S54 [[Free Full Text](#)].
9. Meurice, J. C., I. Marc, and F. Sériès. 1996. Efficiency of auto-CPAP in the treatment of obstructive sleep apnea/hypopnea syndrome. *Am. J. Respir. Crit. Care Med.* 153: 794-798 [[Abstract](#)].
10. Sériès, F., and I. Marc. 1997. Efficacy of automatic continuous positive airway pressure that uses an estimated required pressure level in the treatment of obstructive sleep apnea syndrome. *Ann. Intern. Med.* 8: 588-595 .
11. Johns, M. W.. 1993. Daytime sleepiness, snoring, and obstructive sleep apnea. The Epworth sleepiness scale. *Chest* 103: 30-36 [[Abstract/Free Full Text](#)].
12. Rechtschaffen, A., and A. Kales, editors. 1968. A Manual of Standardized Terminology and Scoring System for Sleep Stages of Human Subjects. Brain Information Service/Brain Research Institute, University of California at Los Angeles.
13. American Sleep Disorders Association. 1992. EEG arousals: scoring rules and examples. *Sleep* 15: 174-183 .

14. Sériès, F., and I. Marc. 1999. Nasal pressure recording in the diagnosis of sleep apnea hypopnea syndrome. *Thorax* 54: 506-510 [[Abstract/Free Full Text](#)].
15. Boudewyns, A., V. Grillier-Lanoir, M. J. Willemen, W. A. De Cock, P. H. Van de Heyning, and W. A. De Backer. 1999. Two months follow up of auto-CPAP treatment in patients with obstructive sleep apnoea. *Thorax* 54: 147-149 [[Abstract/Free Full Text](#)].
16. Ficker, J. H., G. H. Wiest, G. Lehnert, and E. G. Hahn. 1998. Evaluation of an auto-CPAP device for treatment of obstructive sleep apnoea. *Thorax* 53: 643-648 [[Abstract/Free Full Text](#)].
17. Behdehani, K., F. Yen, E. Lucas, and J. Burk. 1998. A sleep laboratory evaluation of an automatic positive airway pressure system for treatment of obstructive sleep apnea. *Sleep* 21: 485-491 [[Medline](#)].
18. Lloberes, P., E. Ballester, J. M. Montserrat, E. Botifoll, A. Ramirez, A. Reolid, C. Gistau, and R. Rodriguez-Roisin. 1996. Comparison of manual and automatic CPAP titration in patients with sleep apnea/ hypopnea syndrome. *Am. J. Respir. Crit. Care Med.* 154: 1755-1758 [[Abstract](#)].
19. Teschler, E., M Berthon-Jones, A. B. Thompson, A. Henkel, J. Henry, and N. Konietzko. 1996. Automated continuous positive airway pressure titration for obstructive sleep apnea syndrome. *Am. J. Respir. Crit. Care Med.* 154: 734-740

Titration Examination

Select the best answer to each of the following items. Mark your responses on the Answer Form.

1. Continuous positive airway pressure (CPAP) is the treatment of choice for patients diagnosed with severe _____.

- a. restless leg syndrome
- b. obstructive sleep apnea (OSA)
- c. night terrors
- d. All of the above

2. In an effort to expedite treatment, maximize resource utilization, and contain costs, many sleep centers have adopted _____ polysomnographic studies for the diagnosis and treatment of this patient population.

- a. shorter duration
- b. split-night
- c. paperless
- d. None of the above

3. The results of the first study shown in this course demonstrate that daytime CPAP titration may be a viable alternative for some patients with severe OSA syndrome. While the inclusion criteria required patients to have _____, further research will be required to accurately determine the ideal patient profile of those most likely to benefit from daytime CPAP titration studies.

- a. regular nocturnal sleep schedules
- b. manifestations of severe OSA
- c. polysomnographic corroboration of severe OSA
- d. All of the above

4. Perhaps the most relevant issue concerning the viability of daytime CPAP titration is the outcome reported by the patients after _____ of treatment.

- a. 1 week
- b. twenty days
- c. 1 month
- d. 3 months

5. Excessive utilization of daytime CPAP titration may potentially result in an increased percentage of CPAP failures. Patients with milder degrees of apnea should always be titrated during their regular sleep period.

- a. True
- b. False

6. _____ titration in a sleep laboratory is costly and limits access for diagnostic studies. Many factors affect compliance, but education and support, rather than in-laboratory titration, appear to be pivotal.

- a. Manual continuous positive airway pressure (CPAP)

- b. Automatic continuous positive airway pressure (CPAP)
- c. Nasal continuous positive airway pressure (nCPAP)
- d. None of the above

7. In the study here that looked at whether or not patients with Obstructive Sleep Apnea can titrate their own continuous positive airway pressure, testing was performed before and after CPAP treatment in each of two 5-week study limbs. CPAP and _____ were performed.

- a. compliance with CPAP treatment
- b. the Sleep Apnea Quality of Life Index
- c. the Functional Outcomes of Sleep Questionnaire score
- d. All of the above

8. CPAP titration to discern the optimal pressure required to alleviate upper airway obstruction during sleep usually includes a simultaneous recording of _____ and is typically conducted in a sleep laboratory.

- a. sleep
- b. respiration
- c. oxygen saturation
- d. All of the above

9. The determination of the effective pressure level (Peff) is realized during a titration sleep study that is routinely achieved during in-laboratory sleep studies and consists of the continuous acquisition of _____.

- a. electrophysiologic
- b. ventilatory
- c. transcutaneous SaO₂ characteristics
- d. All of the above

10. There is yet no consensus about what constitutes the most effective and cost-efficient CPAP titration protocol.

- a. True
- b. False

11. Since its original description in _____, continuous positive airway pressure (CPAP) has become the standard treatment for OSA.

- a. 1965
- b. 1971
- c. 1981
- d. 1995

12. The _____ is a useful measure of disease-specific quality of life and, in particular, has the ability to incorporate negative effects of CPAP into the overall pre-to post-CPAP response.

- a. Epworth Sleepiness Scale
- b. Sleep Apnea Quality of Life Index
- c. Functional Outcomes of Sleep Questionnaire score
- d. None of the above

13. Nasal continuous positive airway pressure (nCPAP) is the therapy of choice for patients with moderate-to-severe symptomatic sleep apnea as it has been shown to improve quality of life and cardiovascular risk factors such as arterial hypertension in controlled trials. The pressure applied during long-term treatment is generally determined by a technician in the sleep laboratory on the basis of a continuous polysomnographic recording. The treatment pressure is increased until _____ are prevented during all sleep stages and in the supine position.

- a. apneas
- b. hypopneas
- c. snoring
- d. All of the above

14. In the study of Autotitrating continuous positive airway pressure (CPAP) devices which automatically adjust the pressure according to upper airway obstructions, the number of all electroencephalographic arousals per hour of sleep was defined as the total arousal index. The respiratory arousal index was defined as the number of respiratory disturbances (such as _____) accompanied by electroencephalographic arousal per hour of sleep.

- a. apneas
- b. hypopneas
- c. snoring episodes
- d. All of the above

15. Patients with OSA are capable of effective self-titration of CPAP treatment at home.

- a. True
- b. False

MEDEDSYS
PO BOX 81831, San Diego, CA, 92138-3939
TOLL FREE 1-877-295-4719
FAX: 619-295-0252
info@mededsys.com
www.mededsys.com

How to Complete Your Test and Print Your Certificate Online

If you chose to receive your order by postal mail, you have been mailed the printed course material(s) and the printed test(s). To take a test, simply complete the mailed test and send it back. Upon successful completion of a test, a certificate will be mailed or faxed to you. If you don't wish to mail the test back, customers who chose to have the course material(s) mailed may also follow the steps below to complete a test and print a certificate online.

INSTRUCTIONS

1. Go to www.mededsys.com
2. Login and go to "My Account".
3. On the page that opens, select an option from the "My Courses" menu.
4. Select the test you wish to complete.
5. After completion of test, print your certificate online by clicking on the "Continue" button. Alternatively, you may return to the "My Courses" section and select the option to print a certificate.