Sleep Breath (2008) 12:235–241
DOI 10.1007/s11325-007-0158-2

ORIGINAL ARTICLE

Autotitration positive airway pressure therapy in patients with obstructive sleep apnea who are intolerant of fixed continuous positive airway pressure

James M. Parish · Bernie W. Miller · Joseph G. Hentz

Published online: 28 November 2007

Abstract Compliance with continuous positive airway pressure (CPAP) therapy is one of the most difficult management problems for patients with obstructive sleep apnea (OSA). We postulated that autotitration positive airway pressure (APAP) may be effective in some patients who have an intolerance of fixed CPAP. The study was done to estimate how often patients who cannot tolerate fixed CPAP can tolerate APAP. We identified 25 patients seen in the Sleep Disorders Center who had been treated with fixed CPAP for OSA and were intolerant of CPAP therapy despite multiple efforts to improve tolerance. We substituted APAP therapy and measured subjective and objective compliance with treatment 1 month later. The primary end point was the number of patients who successfully tolerated the use of APAP at the end of 30 days, measured objectively by the device's compliance monitor. A positive outcome was defined as an average use of APAP that was greater than 3 h per night on more than 70% of possible nights. Of the 25 patients (mean age, 68 years; mean apnea–hypopnea index, 35), 11 were able to tolerate APAP therapy. The mean number of hours of use in these responders was 6.2; the mean percentage of nights of use among responders was 89%. Determinants of successful APAP use were an apnea-hypopnea index (AHI) less than 18, male sex, OSA related to rapid eye movement, and a high body mass index. APAP therapy may be an effective option in patients who do not tolerate fixed-CPAP therapy.

Keywords Autotitration positive airway pressure · Body mass index · Continuous positive airway pressure · CPAP · Obstructive sleep apnea · Rapid eye movements

J. M. Parish (✉)
Division of Pulmonary Medicine, Mayo Clinic,
13400 East Shea Boulevard,
Scottsdale, AZ 85259, USA
e-mail: parish.james@mayo.edu

B. W. Miller
Sleep Disorders Center, Mayo Clinic,
13400 East Shea Boulevard,
Scottsdale, AZ 85259, USA

J. G. Hentz
Biostatistics Unit, Mayo Clinic,
13400 East Shea Boulevard,
Scottsdale, AZ 85259, USA

Introduction

Obstructive sleep apnea (OSA) is a common medical condition associated with several serious health effects, including excessive daytime sleepiness, increased incidence of automobile accidents, poor quality of life, and increased prevalence of cardiovascular disease [1–3]. The optimal treatment of OSA is positive airway pressure [4–6]. The therapy is most commonly administered as a single fixed pressure delivered through a nasal mask. The fixed continuous positive airway pressure (CPAP) is usually determined during laboratory-based polysomnography by incremental adjustments in pressure to eliminate episodes of apnea, hypopnea, and snoring when the patient is in supine and nonsupine positions and during rapid eye movement (REM) sleep and non-REM sleep. The effective pressure in CPAP therapy is often defined as the pressure that eliminates obstructive events during REM sleep in the

supine position. Therefore, the prescribed pressure is often the highest pressure required to eliminate upper airway obstruction during sleep. Consequently, the patient is over-treated at other times during sleep when a lower pressure would be adequate.

CPAP has been shown to effectively treat OSA and relieve associated symptoms and to improve cardiovascular outcomes [7–9]. One of the most difficult management problems in the practice of sleep medicine is patients' intolerance of CPAP. The overall tolerance level of CPAP quoted in the medical literature varies from about 40 to 80% [9–12]. Engleman and Wild [13] reviewed the medical literature on CPAP adherence and cited an initial refusal rate to use CPAP of 5 to 50% on the basis of nine studies and, of patients who initially accepted CPAP, a rate of discontinuation of 12 to 25% on the basis of 33 studies. Kakkar and Berry [14] have also recently reviewed the literature on CPAP adherence and cited rates of 40 to 80% in various studies. These rates mean that many patients do not tolerate CPAP well and do not receive effective treatment. These patients are then evaluated for alternative treatment, such as an oral appliance or surgical intervention in the upper airway. Each of these alternatives has drawbacks, however, and none is completely successful.

Technology for autoadjustment of positive airway pressure therapy has been developed by various commercial companies in an attempt to improve fixed-CPAP treatment. The resulting devices are referred to as autotitration CPAP, "auto-PAP," or APAP [15–17]. APAP is designed to continuously change the airway pressure in response to flow limitation or airway resistance. Multiple studies have shown that APAP successfully treats OSA [18, 19]. However, APAP devices are typically more expensive than fixed-CPAP devices, and hence, they have not achieved widespread use in clinical practice.

We hypothesized that some patients with intolerance of fixed CPAP may be able to tolerate APAP. The purpose of this study was to identify patients who had reported their intolerance of fixed CPAP and had quit using the device and to treat these patients with an APAP device and to measure their compliance with APAP therapy.

Materials and methods

The study was approved by the Mayo Clinic Institutional Review Board. Patients provided written informed consent before enrolling in the study. The study group consisted of patients who were seen in consultation at the Mayo Clinic Arizona Sleep Disorders Center, who had previously received a diagnosis of OSA, and who had received a prescription for CPAP therapy. Patients were recruited into the study if they reported during a follow-up visit that they were unable to tolerate CPAP therapy and were ready to return the CPAP unit to the home health vendor.

Each patient was seen by a sleep specialist and an experienced sleep technologist who made certain that the CPAP setup was optimal and who provided education and encouragement in the use of CPAP. Different CPAP masks were tried until the mask most comfortable for the patient was found. The mask was fitted carefully to provide patient comfort, to avoid pressure on any area of the face, and to eliminate air leaks. Heated humidification was supplied to improve tolerance, and education was provided about the health consequences of OSA and the benefits of CPAP therapy. If a patient was still unable to tolerate CPAP and requested that treatment be discontinued, the patient was offered enrollment in the study.

Each patient had at least two visits for CPAP trouble-shooting before enrollment. The patients were then given an APAP unit (AutoSet Spirit, ResMed, Poway, CA) for use at home for 30 days in place of the CPAP unit. They used the mask that they found most comfortable, and they were seen on an as-needed basis for assistance. Compliance was measured by the hours-of-use data from the APAP unit, downloaded at the end of 30 days or when the patient terminated treatment. We collected data on hours of use per night, number of nights used, number of nights not used, maximum positive pressure, and 95th percentile pressure (defined as the pressure exceeded only 5% of the time during APAP use).

We collected data on each patient, including age, sex, apnea–hypopnea index (AHI), body mass index, lowest O_2 saturation, percentage of total sleep time when O_2 saturation was less than 90%, and whether the patient had positional or REM-related OSA. We defined positional OSA as an AHI in the supine position of at least two times the AHI in the nonsupine position. We defined REM-related OSA as an AHI in REM sleep of at least two times the AHI in non-REM sleep.

Statistical analysis

The primary outcome measure was whether the patient tolerated APAP treatment. The study protocol defined tolerance as at least 3 h of use per night for 70% or more of possible nights. We reported the percentage of patients who tolerated APAP, and the statistical uncertainty was quantified by using the exact binomial method. The study protocol stated that the result would be considered clinically significant if at least 20% of the patients tolerated APAP. A sample size of 25 patients was selected so that the margin of error (half of the range of the 95% confidence interval [CI]) for the percentage of patients who tolerated APAP would be less than 20 percentage points. The CIs for continuous measures were calculated by using the *t* statistic.

The means and proportions for the patients who tolerated APAP were compared with those of the patients who did not tolerate APAP, and statistical significance was calculated using the two-sample *t* test or Fisher exact test. We also quantified the predictive value of each variable for predicting tolerance to APAP. A cutoff level for continuous measures was selected by using receiver-operating characteristics analysis. We report results for the cutoff levels that yielded the highest likelihood ratio for prediction of a positive response to APAP therapy. The percentage of patients who tolerated APAP among those whose level was above the cutoff was compared with the percentage of patients who tolerated APAP among those whose level was below the cutoff, and the statistical significance was calculated by use of the Fisher exact test. The statistical uncertainty of the probability of response was calculated by use of the exact binomial method. *P* values less than 0.050 were considered to be statistically significant.

Results

During the study period, 33 patients were seen in follow-up who reported that they were unable to tolerate CPAP, had stopped using it, wanted to discontinue attempts at therapy, and returned their CPAP unit. Seven patients declined enrollment in the study, and one patient consented to enrollment but then did not follow through. Of the initial 33 patients, 25 were successfully recruited to enroll in the study. Their characteristics are listed in Table 1. The mean age was 68 years, and the mean body mass index was 31.7 (range, 21.8–50.3). Eight were female, and 17 were male. Before the study, all patients reported that they had stopped using their CPAP unit, and thus we assumed that the patients used their unit for 0 h per night. The mean fixed CPAP pressure for the study group was 10.6 cm H_2O (range, 8–16 cm H_2O).

At the end of the study period, 11 patients (44%) were using APAP on a regular basis, defined as more than 3 h of use per night on more than 70% of possible nights. These patients were considered responders. If we used a threshold of 4 h per night, then nine patients (36%) would be considered responders. Fourteen patients (56%) were using APAP for less than 3 h per night, and these participants were considered nonresponders.

The percentage of responders was significantly higher than 20%, which the study protocol defined as a clinically significant effect. The 95% CI indicated that the percentage of responders in the target population was unlikely to be lower than 24% or higher than 65%. Characteristics of the

Table 1 Characteristics of study group patients with obstructive sleep apnea

Characteristic	Value[a]	95% CI
Age, year (*N*=25)	68±10	64–72
Female sex (*N*=25)	32% (8)	15–54%
Height, in. (*N*=25)	67.9±3.3	67–69
Weight, lb (*N*=25)	202±39	186–218
BMI (*N*=25)	31.7±6.6	29–34
AHI (*n*=21[b])	35±28	22–47
Presence of positional OSA (*n*=21[b])	24% (5)	8–47%
Presence of REM-related OSA (*n*=21[b])	19% (4)	5–42%
Lowest O_2 saturation percent (*n*=21[b])	79±12	74–85
Percentage of total sleep time O_2 saturation<90% (*n*=21[b])	15±20	6–24
Total APAP use, h (*N*=25)	92±90	55–129
APAP use, h/night (*N*=25)	3.9±3.2	2.6–5.2
APAP use, nights (*N*=25)	18±12	13–23
No APAP use, nights[c] (*n*=23[d])	36±62	9–63
Percentage of nights of APAP use (*N*=25)	52±39	36–68
Responders (*N*=25)	44% (11)	24–65%
APAP pressure 95th percentile, cm H_2O (*n*=23[d])	9.1±2.5	8.0–10.1
Maximum APAP pressure, cm H_2O (*n*=23[d])	10.2±3.2	8.9–11.6
Prescribed fixed CPAP pressure, cm H_2O (*N*=25)	10.6±2.9	9.4–11.8

AHI Apnea–hypopnea index, *APAP* autotitration positive airway pressure, *BMI* body mass index, *CI* confidence interval, *CPAP* continuous positive airway pressure, *OSA* obstructive sleep apnea, *REM* rapid eye movement

[a] Categorical data are expressed as percentage and number of patients; continuous data are expressed as mean±SD.

[b] Four patients had diagnostic studies done at other institutions, and data regarding positional relationships and REM relationship from their primary sleep studies were not available.

[c] Five patients kept the device longer than the 30-day study limit.

[d] Two patients in the study group did not use APAP at all.

two groups are listed in Table 2. Four patients had diagnostic studies done at other institutions and were seen at our sleep center for further consultation related to intolerance to CPAP; we did not have access to the data from their primary sleep studies.

We examined our data also to identify features associated with a higher probability of successful use of APAP. In younger, male patients with a high body mass index, low AHI, and REM-related OSA, the percentage of responders was higher than in the other patients in this sample (Table 3). The AHI (P=0.02) and REM-related OSA (P=0.02) were characteristics that had the strongest relationship with response: The percentage of responders was 86% among patients whose AHI was less than or equal to 17 per hour compared with 21% among patients whose AHI was 18 per hour or greater. All four patients with REM-related OSA responded, compared with 5 of 17 patients without REM-related OSA.

Discussion

Several studies have compared tolerance of APAP with tolerance of fixed CPAP in newly treated patients with OSA. Generally, the two treatments have been found to be equivalent in efficacy [18–22]. However, there has not been a study to determine whether APAP is a viable treatment alternative in patients who have tried fixed CPAP and were intolerant of this therapy. In the present series, 11 of 25 patients (44%) who were giving up on fixed-CPAP therapy found that APAP was an alternative treatment that they were able to tolerate. Even if we would include as nonresponders the eight patients who met the study's criteria but did not enroll in the study, we would find that 33% of patients responded to APAP as an alternative treatment. In addition, younger age, male sex, less severe OSA, higher body mass index, and REM-related OSA were determinants of tolerance of APAP over CPAP.

Poor compliance with CPAP therapy remains one of the most difficult management problems for patients with OSA. Many patients do not tolerate CPAP well, and in them, successful treatment remains elusive. The reasons why patients do not tolerate CPAP are many. Patients may reject having any device covering their nose or mouth or both and perceive it as simply unattractive or undesirable. They may not understand the reasons for CPAP therapy and why they are using it. They may have a poorly fitting mask that causes intolerable pressure on the nose, forehead, or face,

Table 2 Measures for responders to autotitration positive airway pressure compared with nonresponders

	Responders[a]		Nonresponders[a]				
Measure	Value	Number	Value	Number[c]	Δ	95% CI	P value[b]
Age, year	65±11	11	70.4±8.9	14	−5.8	−14 to 2	0.16
Female sex	27% (3)	11	36% (5)	14	−0.08	−0.46 to 0.32	1.00
Height, in.	67.9±4.0	11	67.9±2.8	14	0.0	−2.8 to 2.9	0.97
Weight, lb	215±32	11	192±42	14	22	−9 to 54	0.16
BMI	33.2±7.6	11	30.4±5.7	14	2.8	−2.7 to 8.3	0.31
AHI	17±19	9[d]	48±26	12[d]	−30	−52 to −9	0.009
Presence of positional OSA	22% (2)	9[d]	25% (3)	12[d]	−0.03	−0.41 to 0.39	1.00
Presence of REM-related OSA	44% (4)	9[d]	0% (0)	12[d]	0.44	0.09 to 0.79	0.02
Lowest O_2 saturation %	82.1±7.0	9[d]	77±15	12[d]	5.3	−6 to 17	0.34
Percentage of total sleep time O_2 saturation<90%	6±16	9[d]	22±22	12[d]	−16	−33 to 2	0.08
Total APAP use, h	179±59	11	24±31	14	156	118 to 193	<0.001
APAP use, h/nights	6.2±1.7	11	2.0±2.8	14	4.2	2.2 to 6.2	<0.001
APAP use, nights	29.6±4.1	11	9.2±7.5	14	20	15 to 26	<0.001
No APAP use, nights[e]	3.8±3.2	11	66±76	14	−62	−110 to −14	0.01
Percentage of nights of APAP use	89.1±8.7	11	23±25	14	66	50 to 83	<0.001
APAP pressure 95th percentile, cm H_2O	9.4±1.3	11	8.7±3.2	14	0.8	−1.4 to 2.9	0.48
Maximum APAP pressure, cm H_2O	10.6±1.3	11	10.0±4.3	14	0.6	−2.2 to 3.5	0.65
Prescribed fixed CPAP pressure, cm H_2O	10.3±3.6	11	10.8±2.4	14	−0.5	−3.0 to 2.0	0.67

AHI Apnea–hypopnea index, *APAP* autotitration positive airway pressure, *BMI* body mass index, *CI* confidence interval, *CPAP* continuous positive airway pressure, *OSA* obstructive sleep apnea, *REM* rapid eye movement

[a] Categorical data are expressed as percentage and number of patients; continuous data are expressed as mean±SD.

[b] Nominal P values of less than 0.003 are significant (α=0.05) when accounting for 18 comparisons with the Bonferonni method.

[c] Two patients in the study group did not use APAP at all.

[d] Four patients had diagnostic studies done at other institutions, and data regarding positional relationships and REM relationship from their primary sleep studies were not available.

[e] Five patients kept the device longer than the 30-day study limit.

Table 3 Positive response to autotitration positive airway pressure among patients who did and did not meet the criteria

	Patients with positive response					
	Patients meeting criterion			Patients not meeting criterion		
Criterion for prediction of positive response to APAP	Number/*n*	Percent	95% CI (%)	Number/*n*	Percent	95% CI (%)
Age≤56 years	3/4	75	19–99	8/21	38	18–62
Male sex	8/17	47	23–72	3/8	38	9–76
Height>72 in.	1/1	100	0–98	10/24	42	22–63
Weight>204.8 lb	6/11	55	23–83	5/14	36	13–65
BMI>39.2	2/3	67	9–99	9/22	41	21–64
AHI≤17	6/7[a]	86	42–100	3/14[a]	21	5–51
Presence of positional OSA	7/16[a]	44	20–70	2/5[a]	40	5–85
Presence of REM-related OSA	4/4[a]	100	0–60	5/17[a]	29	10–56
Lowest O_2 saturation>86%	2/3[a]	67	9–99	7/18[a]	39	17–64
Percentage of total sleep time below O_2 saturation 90%≤1.2%	8/10[a]	80	44–97	1/11[a]	9	0–41
Total APAP use>81 h	10/11	91	59–100	1/14	7	0–34
APAP use>3.97 h/night	9/11	82	48–98	2/14	14	2–43
APAP use>23 nights	10/10	100	0–31	1/15	7	0–32
No APAP use≤10 nights	11/12[b]	92	62–100	0/11[b]	0	0–28
Percentage of nights of APAP use>70%	11/11	100	0–28	0/14	0	0–23
APAP pressure in 95th percentile>8.2 cm H_2O	9/16[b]	56	30–80	2/7[b]	29	4–71
Maximum APAP pressure>9.4 cm H_2O	9/16[b]	56	30–80	2/7[b]	29	4–71
Prescribed fixed CPAP pressure≤7 cm H_2O	2/2	100	0–84	9/23	39	20–61

AHI Apnea–hypopnea index, *APAP* autotitration positive airway pressure, *BMI* body mass index, *CI* confidence interval, *CPAP* continuous positive airway pressure, *OSA* obstructive sleep apnea, *REM* rapid eye movement

[a] Four patients had diagnostic studies done at other institutions, and data regarding positional relationships and REM relationship from their primary sleep studies were not available.

[b] Two patients in the study group did not use APAP at all.

or their mask may have an air leak that causes eye irritation. In addition, patients may not tolerate the resistance to exhalation caused by higher treatment pressures. Nasal irritation may result either from low humidity in the CPAP airflow or from the high treatment pressure itself.

APAP offers an alternative to fixed CPAP and can be used in potentially two ways: (1) in the sleep laboratory or at home to determine a fixed pressure for CPAP that is then prescribed for long-term use and (2) as long-term treatment in place of fixed CPAP. We speculated that because the severity of upper airway obstruction varies by sleep state and body position, APAP might be an effective alternative to fixed CPAP. APAP delivers effective CPAP pressure when airway obstruction or flow limitation is detected and then decreases the pressure to a lower level when no obstruction is present. Thus, many patients may find APAP a more comfortable therapy than fixed CPAP.

APAP devices are made by several manufacturers, and their operation is based on unique proprietary algorithms that determine how each device detects and responds to airway obstruction or flow limitation [23]. The operation of some devices is based on algorithms that account for vibration within the airway, others on algorithms that account for flow limitation, and yet others on both types of algorithms. Several studies have shown that all APAP devices do not respond in the same way. When tested by mechanical flow generators simulating apnea, hypopnea, and other variations of flow limitation, the devices of different manufacturers responded differently [24, 25]. Machine response is, therefore, based on the algorithm used. Therefore, it is possible that the clinical effect of one brand of APAP device may not be the same as that of another brand based on a different algorithm. One study showed different clinical outcomes in patients who each used three different APAP units [26].

Our study has important limitations, one being study design. We devised this preliminary study with a single-cohort design. Initially, we considered a randomized crossover design, but we believed that because the patients would have already had a negative experience with CPAP, it would be difficult to enroll patients in a study with a placebo group. The placebo arm's protocol would have been either fixed CPAP, which we knew this patient group would not tolerate well, or a sham CPAP. The sham CPAP would not have been an appropriate option because the question was not whether CPAP worked—that fact had

already been established—but whether APAP was an effective therapy in patients who did not tolerate fixed CPAP. Because of the previous negative response to CPAP in this group, it was sometimes difficult to convince patients to try one more pressurized device. We therefore decided that as an initial test of a concept, the study would use a single-cohort design because we believed that patients would either accept APAP or not. In addition, a larger sample would have yielded a more accurate measure of tolerance to APAP, and a controlled study would have better distinguished the effect of autotitration from the effect of a repeated trial of CPAP.

Although the commonly held opinion about the definition of adequate CPAP adherence has defined it as 4 h of use per night, our clinical impression was that many patients obtained benefit from only 3 h of CPAP use during split night studies. We decided to use this 3-h definition for CPAP adherence for our study. This concept was validated by a recent study by Weaver et al. [27], which showed a "dose-response" effect on the Multiple Sleep Latency Test, the Epworth Sleepiness Scale, and the Functional Outcomes of Sleep Questionnaire with CPAP use. Compared with less than 2 h of CPAP use, 2 to 4 h of use led to a significant increase in each of those end points and to a further increment in outcome scores with each increase in hours of CPAP use. The authors showed that among the patients who used CPAP for 2 to 4 h per night, 68.8% of patients with abnormal pretreatment values on the Epworth Sleepiness Scale had normal values after 3 months of treatment, 35.5% of patients had normalized their scores on the Multiple Sleep Latency Test, and 43.5% of patients had normalized their scores on the Functional Outcomes of Sleep Questionnaire [10].

Before enrollment in the study, all patients received counseling several times on the adverse health consequences of OSA and the potential benefits of CPAP therapy. Each patient had opportunities during follow-up to try several different masks and was usually able to find a mask that was comfortable. In addition, each patient received a heated humidifier to help tolerance.

We had selected a group of patients intolerant of CPAP despite the best efforts of our sleep center team to help them with the therapy. Although the group was a narrowly defined one, it was a group of patients with characteristics that are often seen in a typical sleep center practice. We conclude that clinically, APAP may be an effective option in patients who do not tolerate fixed-CPAP therapy. Larger studies are necessary to provide further data to support this concept.

Acknowledgment Editing, proofreading, and reference verification were provided by the Section of Scientific Publications, Mayo Clinic. This study was supported by a grant from ResMed, Poway, CA.

References

1. Young T, Palta M, Dempsey J et al (1993) The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 328:1230–1235
2. Caples SM, Gami AS, Somers VK (2005) Obstructive sleep apnea. Ann Intern Med 142:187–197
3. White DP (2006) Sleep apnea. Proc Am Thorac Soc 3:124–128
4. Farre R, Hernandez L, Montserrat JM et al (1999) Sham continuous positive airway pressure for placebo-controlled studies in sleep apnoea. Lancet 353:1154
5. Jenkinson C, Davies RJ, Mullins R et al (1999) Comparison of therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: a randomised prospective parallel trial. Lancet 353:2100–2105
6. Montserrat JM, Ferrer M, Hernandez L et al (2001) Effectiveness of CPAP treatment in daytime function in sleep apnea syndrome: a randomized controlled study with an optimized placebo. Am J Respir Crit Care Med 164:608–613
7. Engleman HM, Douglas NJ (2004) Sleep. 4. Sleepiness, congestive function, and quality of life in obstructive sleep apnoea/hypopnoea syndrome. Thorax 59:618–622
8. Doherty LS, Kiely JL, Swan V et al (2005) Long-term effects of nasal continuous positive airway pressure therapy on cardiovascular outcomes in sleep apnea syndrome. Chest 127:2076–2084
9. Gay P, Weaver T, Loube D et al (2006) Positive Airway Pressure Task Force, Standards of Practice Committee, American Academy of Sleep Medicine. Evaluation of positive airway pressure treatment for sleep related breathing disorders in adults. Sleep 29:381–401
10. Kribbs NB, Pack AI, Kline LR et al (1993) Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea. Am Rev Respir Dis 147:887–895
11. McArdle N, Devereaux G, Heidarnejad H et al (1999) Long-term use of CPAP therapy for sleep apnea/hypopnea syndrome. Am J Respir Crit Care Med 159:1108–1114
12. Zozula R, Rosen R (2001) Compliance with continuous positive airway pressure therapy: assessing and improving treatment outcomes. Curr Opin Pulm Med 7:391–398
13. Engleman HM, Wild MR (2003) Improving CPAP use by patients with the sleep apnoea/hypopnoea syndrome (SAHS). Sleep Med Rev 7:81–99
14. Kakkar RK, Berry RB (2007) Positive airway pressure treatment for obstructive sleep apnea. Chest 132:1057–1072
15. Berkani M, Lofaso F, Chouaid C et al (1998) CPAP titration by an auto-CPAP device based on snoring detection: a clinical trial and economic considerations. Eur Respir J 12:759–763
16. d'Ortho MP, Grillier-Lanoir V, Levy P et al (2000) Constant vs. automatic continuous positive airway pressure therapy: home evaluation. Chest 118:1010–1017
17. Meurice JC, Marc I, Series F (1996) Efficacy of auto-CPAP in the treatment of obstructive sleep apnea/hypopnea syndrome. Am J Respir Crit Care Med 153:794–798
18. Berry RB, Parish JM, Hartse KM (2002) The use of auto-titrating continuous positive airway pressure for treatment of adult obstructive sleep apnea: an American Academy of Sleep Medicine review. Sleep 25:148–173
19. d'Ortho MP (2004) Auto-titrating continuous positive airway pressure for treating adult patients with sleep apnea syndrome. Curr Opin Pulm Med 10:495–499
20. Hukins C (2004) Comparative study of autotitrating and fixed-pressure CPAP in the home: a randomized, single-blind crossover trial. Sleep 27:1512–1517
21. Massie CA, McArdle N, Hart RW et al (2003) Comparison between automatic and fixed positive airway pressure therapy in the home. Am J Resp Crit Care Med 167:20–23

22. Littner M, Hirshkowitz M, Davila D et al (2002) Standards of practice committeee of the American academy of sleep medicine. Sleep 5:143–147
23. Loube DI (1999) Technologic advances in the treatment of obstructive sleep apnea syndrome. Chest 116:1426–1433
24. Rigau J, Montserrat JM, Wohrle H et al (2006) Bench model to simulate upper airway obstruction for analyzing automatic continuous positive airway pressure devices. Chest 130:350–361
25. Lofaso F, Desmarais G, Leroux K et al (2006) Bench evaluation of flow limitation detection by automated continuous positive airway pressure devices. Chest 130:343–349
26. Nolan GM, Ryan S, O'Connor TM et al (2006) Comparison of three auto-adjusting positive pressure devices in patients with sleep apnoea. Eur Respir J 28:159–164
27. Weaver TE, Maislin G, Dinges DF et al (2007) Relationship between hours of CPAP use and achieving normal levels of sleepiness and daily functioning. Sleep 30:711–9