Long-term Use of CPAP Therapy for Sleep Apnea/Hypopnea Syndrome

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Patients with the sleep apnea/hypopnea syndrome (SAHS) treated by nasal continuous positive airway pressure (CPAP) need to use CPAP long-term to prevent recurrence of symptoms. It is thus important to clarify the level of long-term CPAP use and the factors influencing long-term use. We examined determinants of objective CPAP use in 1,211 consecutive patients with SAHS who were prescribed a CPAP trial between 1986 and 1997. Prospective CPAP use data were available in 1,155 (95.4%), with a median follow-up of 22 mo (interquartile range [IQR], 12 to 36 mo). Fifty-two (4.5%) patients refused CPAP treatment (these were more often female and current smokers); 1,103 patients took CPAP home, and during follow-up 20% stopped treatment, primarily because of a lack of benefit. Methods of survival analysis showed that 68% of patients continued treatment at 5 yr. Independent predictors of long-term CPAP use were snoring history, apnea/hypopnea index (AHI), and Epworth score; 86% of patients with Epworth $>$ 10 and an AHI $\geqslant$ 30 were still using CPAP at 3 yr. Average nightly CPAP use within the first 3 mo was strongly predictive of long-term use. We conclude that long-term CPAP use is related to disease severity and subjective sleepiness and can be predicted within 3 mo. McArdle N, Devereux G, Heidarnejad H, Engleman HM, Mackay TW, Douglas NJ. Long-term use of CPAP therapy for sleep apnea/hypopnea syndrome.

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The sleep apnea/hypopnea syndrome (SAHS) occurs in 2 to 4% of the middle aged population (1) causing impaired daytime functioning as a result of excessive daytime somnolence, cognitive impairment and altered mood (2, 3). The consequences of such impairments are of major concern when they lead to accidents on the road (4, 5) and at work. There is also increasing evidence that SAHS is an independent risk factor for cardiovascular disease (6). Effective treatment for SAHS can be achieved by nasal continuous positive airway pressure (CPAP). CPAP therapy is the treatment of choice for most patients; however, effectiveness continues only while the treatment is being used (7). As SAHS is usually a lifelong condition (8), it is extremely important to ensure long-term use of CPAP therapy.

Early studies reported high rates of long-term use (9–12); however, most relied on questionnaire and self-reported use rates. Subsequent studies, using data recorded from time clocks built into the CPAP machines, have shown that early figures were overestimates and that objective use is lower (13, 14), often irregular, and rarely meets the prescribed level (15, 16). There are few studies of objective long-term use of CPAP; only one (17) could be found involving more than 50 patients with a mean follow-up time of more than 1 yr. In order to clarify the important determinants of long-term compliance with CPAP therapy, we reviewed our experience of a large group of patients with SAHS on whom we have prospective objective data on CPAP use. The determinants of compliance that were considered to be important comprised known indices of disease severity, e.g., apnea/hypopnea index (AHI) and common treatment-related variables (e.g., CPAP pressure) as well as basic patient-related variables (e.g., demographics). These variables were chosen since they are, in the main, specific to sleep apnea and likely to be used for decision-making in the sleep clinic setting.

METHODS

Patients

All patients booked for a CPAP titration night between January 1986 and February 1997 at the Scottish National Sleep Center were studied. Data were obtained from review of all clinical records, patient and spouse questionnaires completed at the time of the original consultation, sleep study results, and objective CPAP use records. Patients with kyphoscoliosis or neuromuscular disorders were excluded, but patients with SAHS were not excluded if there was coexisting chronic obstructive airway disease if CPAP alone was the modality of treatment chosen.

Diagnosis

Patients were evaluated for possible SAHS by clinical interview and examination with involvement of a physician experienced in sleep medicine. Results of an overnight sleep study as well as pulmonary function tests, chest radiography, and at times other investigations such as a multiple sleep latency test (MSLT) were reviewed prior to deciding on the need for CPAP treatment. The decision to treat was based on the presence of at least two major symptoms of the SAHS (18) and an appropriate sleep study demonstrating an abnormal num-

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ber of apneas and hypopneas per hour slept (AHI). Apneas were defined as the absence of oronasal airflow in the presence of thoracoabdominal movement for at least 10 s and hypopneas as at least a 50% reduction in thoracoabdominal movement for a minimum of 10 s (19).

Most diagnostic sleep studies were full polysomnography, performed with our usual equipment, and scoring techniques (19). Limited sleep studies without electroencephalographic recording such as the Autoset (ResMed Ltd., North Ryde, NSW, Australia) and EdenTec (EdenTec Corp., Eden Prairie, MN) systems, as well as overnight oximetry, were also used.

The cutoff for an abnormal AHI warranting treatment, when accompanied by appropriate symptoms, has varied over the study period, but it has always been between more than five or more than 15 events per hour for polysomnographic studies. CPAP treatment based on limited sleep studies required an apnea/hypopnea score of greater than 30 events per hour in bed.

CPAP Titration and Follow-up

All patients received education prior to a CPAP titration night. This involved an explanation of the treatment by a specialized CPAP nurse, mask-fitting from a wide range of more than 20 mask types, an educational video, and 20 min spent acclimatizing to CPAP on a bed during the daytime. Most CPAP titration was performed manually to obtain the minimum pressure that normalized breathing pattern and minimized EEG arousals (13). Latterly, the Autoset (ResMed) system was used occasionally. Since 1990 all patients have been issued CPAP machines with in-built time clocks that record the time the machine is switched on.

During the first 2 wk after taking CPAP home patients were usually contacted by the nurse specialists on one occasion. At times additional calls were made if there were on-going problems. The average duration of these phone calls was approximately 10 to 15 min.

Patients were asked about the effect of treatment on nighttime and daytime disease symptoms, then difficulties with use of CPAP were sought. Interface problems were addressed by changing mask type or headgear. The mask types most commonly used were the Respironics mask (Respironics, Marysville, PA) in about two-thirds of patients and the Sullivan Bubble mask (ResMed) in almost one-third. An Adams circuit (Mallinckrodt Ltd, St. Louis, MO) was used in 32 patients to provide relief to skin pressure areas, especially to the nasal bridge. Only 12 patients continued Adams circuits long-term. Full face masks were used in fewer than 10 patients. Nasal/oral symptoms were treated with topical decongestants or humidifiers, and antihistamines were not used. Patients were reviewed in the sleep center by nursing staff if problems could not be resolved by phone. Further support was available by 24-h access to a telephone advice line manned by the CPAP nurse specialists. Clinic follow-up occurred initially within 3 mo of starting CPAP. Subsequent reviews became less frequent as patients were established on treatment, with a maximum of 12 mo between reviews. At each review a clinical assessment was made and the CPAP time clock was read to compute the average nightly rate of use. CPAP machines were provided free of charge to patients. Those whose objective CPAP use was < 2 h at any clinic appointment were confronted with their usage data and encouraged to increase their CPAP use. Any problems with CPAP side effects were addressed, and a 1-mo review appointment was made. If subsequent use was still < 2 h the CPAP machine was then reclaimed by the Sleep Center.

Statistical Analysis

Statistical analysis was performed using the STATA Release 4 statistical package (Computing Resource Center, Santa Monica, CA). Nonparametric methods (Mann-Whitney U test, chi-square, Spearman's rank correlation) were used in the basic descriptive statistical analyses because the variables measured were either dichotomous or categorical, or did not approximate to a normal distribution. The primary dependent variable of interest was possession and continued use of a CPAP machine. The methods of survival analyses (Kaplan-Meier) were used (20) to allow for variable follow-up times. Additionally, the methods of Kaplan-Meier allow use of "censored" data, so that all information gathered up to the time of a censored event can be used. Death, transfer of care, and loss to follow-up were entered as "censored" variables. This provides maximal use of available data because survival information can be analyzed even though the event of interest (deliberate stopping of CPAP treatment) is never reached (20). Univariate analyses (log-rank test) were used to identify possible explanatory variables influencing continued CPAP use. To explore the independent effects of explanatory variables Cox's proportional hazards model was used (20, 21) and expressed as hazard ratios. The use of Cox's method for survival analysis is analogous to the use of multiple regression as an extension of linear regression. Kaplan-Meier analysis allows the use of both continuous and categorical data. For simplicity and relevance to clinical practice, many of the results have been presented using categorical data.

The study had the approval of the local ethics advisory committee.

RESULTS

Study Population

A total of 1,211 patients were booked in for CPAP titration nights, and data were available for 1,155 (95.4%). Follow-up data were unavailable in the remaining 56. Comparison of baseline data on the unavailable patients showed that they were not different from the rest of the group in terms of age, body mass index (BMI), AHI, Epworth score (Mann-Whitney U test, all $p > 0.1$), or sex (chi-square, $p = 0.18$).

Fifty-two patients (4.5%) who were booked for a CPAP titration study subsequently refused CPAP treatment. These patients either repeatedly failed to attend the titration night ($n = 16$) or were unable to tolerate CPAP on the titration night and refused to take CPAP home ($n = 36$). When compared with patients who accepted CPAP therapy, patients who refused CPAP were more often female (31 versus 14%, $p = 0.002$), current smokers (55 versus 32%, $p = 0.003$), and referred by a specialist rather than by a family practitioner (80 versus 61%, $p = 0.01$). Conversely, these patients were less likely to have a history of witnessed apneas (65 versus 83%, $p = 0.004$) and had a lower weekly alcohol consumption (0.5 versus 6 units, $p = 0.008$). Neither severity of sleep apnea, in terms of AHI, nor degree of subjective sleepiness as measured by the Epworth scale were significant predictors of CPAP acceptance (Table 1).

Patients Who Commenced CPAP Therapy

There were 1,103 patients who were commenced on home CPAP therapy; 86% were male and the median age was 50 yr (interquartile range [IQR] = 43 to 58 yr); BMI, 30 (IQR = 27 to 35) kg/m^2; AHI, 31 (IQR = 18 to 53) events/h; Epworth score, 12 (IQR = 8 to 16). The most common clinical features were a history of snoring (98%), witnessed apneas (83%), and excessive daytime somnolence (EDS) (81%). A self-rated Epworth score of greater than 10 was present in 60% of patients, and 36% of patients reported difficulties because of sleepiness while driving (Table 1).

Most cases of SAHS were diagnosed with full night polysomnography (933, 80%) with a small number undergoing a split-night of diagnostic polysomnography followed by CPAP titration (45, 4%). The remainder underwent studies using EdenTec ($n = 135$, 12%), Autoset ($n = 23$, 2%), or oximetry alone ($n = 19$, 2%) for diagnosis. Patients were treated with a median CPAP pressure of 8 cm H_2O (IQR = 7 to 10).

The maximum follow-up duration was 139 mo, with 281 being followed for 3 yr or more and 61 for 5 yr or more. The median follow-up was 22 mo (IQR = 12 to 36), reflecting the exponential rise in referrals during the time of the study. During follow-up 38 patients (3.5%) died (a further two patients who refused CPAP are known to have died), another nine (0.8%) patients had their care transferred to another center, and 217 (20%) stopped CPAP. Of these 217 who stopped CPAP, 167 (77%) independently decided to terminate treatment, and 50

TABLE 1

BASELINE DATA ON PATIENTS REFUSING CPAP COMPARED WITH PATIENTS TAKING CPAP HOME

	Patients Refusing CPAP*	Patients Taking CPAP Home*	p Value
Patients, n	52	1,103	
Female, %	31	14	0.002
Median age, yr	44 (32–57)	50 (43–58)	0.08
Median BMI, kg/m^2	30 (27–36)	30 (27–35)	> 0.1
Median AHI, events/h slept	22 (13–53)	31 (18–53)	0.07
Median arousals events/h slept	25 (17–43)	32 (20–50)	0.08
Median Epworth score	12 (6–17)	12 (8–16)	> 0.1
Current smoker, %	55	32	0.003
Median alcohol consumption, units/wk	0.5 (0–7)	6 (1–16)	0.008
Hospital referral, %	80	61	0.01
History of snoring, %	100	98	> 0.1
History of apneas, %	65	83	0.004
History of daytime somnolence, %	84	81	> 0.1
History of driving problems, %	48	36	> 0.1

Definition of abbreviations: AHI = apnea/hypopnea index; BMI = body mass index; CPAP = continuous positive airway pressure.
* Values in parentheses are interquartile ranges.

(23%) had their machine reclaimed. Of these 50 patients reasons for reclamation were due to either persistent use less than 2 h per night (n = 47) or CPAP-induced severe side effects such as recurrent epistaxis (n = 3). Reasons why patients stopped using CPAP include lack of benefit (n = 112), discomfort (including noise and feelings of claustrophobia) (n = 102), and other reasons (cure as a result of weight loss, recurrent epistaxis, alternative diagnosis, and unknown reasons) (n = 28). There was more than one reason documented in 20 (18%) patients.

The median use per night at the most recent clinic visit for all patients who started home CPAP therapy was 5.6 h (IQR = 3.8 to 7.0) per night and in patients continuing to use CPAP it was 5.7 h (IQR = 3.9 to 7.0) per night. In the latter group, 76% of patients used their CPAP machine for an average of 3.7 h or more per night.

A Kaplan–Meier plot of the percentage of patients started on CPAP who continue using their machine over time shows that 84% were still using CPAP at 12 mo and the use of CPAP reached a plateau at around 4 yr when 68% continued with treatment (Figure 1).

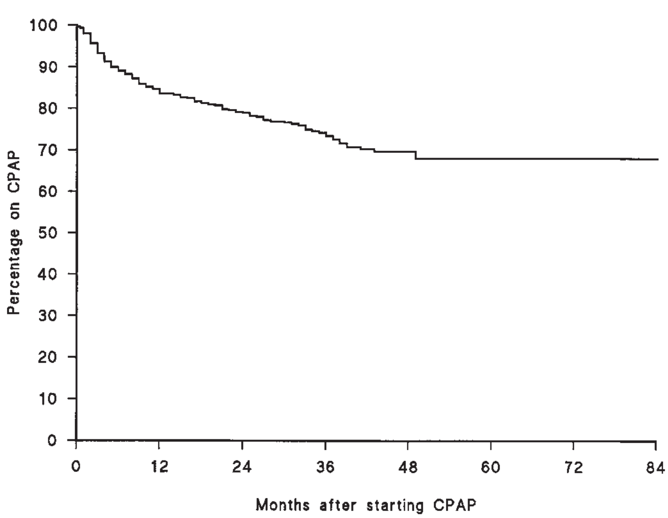

Figure 1. Percentage of patients using CPAP versus time.

Determinants of Long-term CPAP Use

We sought determinants of long-term compliance with CPAP therapy from baseline data and from computed CPAP use at the first clinic follow-up after commencing CPAP therapy (always ⩽ 3 mo). Baseline data comprised patient-related (age, sex, occupation, and referral source), disease-related (symptoms, Epworth score, AHI, arousal index, collar size, BMI, alcohol consumption, smoking status, and coexisting COPD), and treatment-related (diagnostic study type, method of CPAP titration, and CPAP pressure) variables. This analysis indicated that continued use of CPAP therapy was associated with male sex, lower age, absence of COPD, and increasing values for Epworth score, AHI, arousals, BMI, and CPAP pressure. A history of snoring, witnessed apneic episodes, daytime somnolence, and problems with somnolence during driving were also associated with continued use of CPAP therapy. Rate of use of CPAP at the first follow-up visit correlated with long-term CPAP use. The data were also analyzed with continuous variables being categorized by commonly used clinical cutoffs or by median values (Table 2).

Cox's proportional hazards models indicated that the independent predictors of long-term CPAP use were snoring his-

TABLE 2

UNIVARIATE ANALYSIS: VARIABLES INFLUENCING CONTINUED CPAP USE

	Hazard Ratio*	p Value
Women versus men	1.48	0.03
Age ⩾ 50 versus age < 50	1.43	0.001
BMI ⩽ 30 versus BMI > 30	1.65	0.0003
Epworth ⩽ 10 versus Epworth > 10	1.89	< 0.0001
AHI < 15 versus AHI ⩾ 15	2.29	< 0.0001
AHI < 30 versus AHI ⩾ 30	2.26	< 0.0001
Arousals < 32 versus arousals ⩾ 32	1.55	0.0036
Nonsnorer versus snorer	2.6	0.006
No apneas versus apneas	2.25	< 0.0001
No somnolence versus somnolence	2.23	< 0.0001
No driving problems versus driving problems	2.25	< 0.0001
Coexisting COPD versus no COPD	1.6	0.01
CPAP pressure < 8 cm H_2O versus > 8 cm H_2O	1.53	0.002
CPAP usage at 3 mo < 2 h versus ⩾ 2 h	12.7	< 0.0001

For definition of abbreviations, *see* Table 1.
* Relative risk of stopping CPAP.

tory ($p = 0.009$), AHI ⩾ 15 ($p < 0.001$), and Epworth score > 10 ($p < 0.001$) (Table 3). Kaplan-Meier plots show the combined role of AHI and Epworth score on CPAP use at commonly used cutoffs (Figure 2). AHI and Epworth score were independent predictors of continued CPAP use when analyzed as continuous variables, predicting use across the range of their values. CPAP use at the first follow-up clinic visit was also a strong independent predictor of continued CPAP use (Table 3 and Figure 3). Using a cutoff of 2 h or more per night at the first visit, the hazard ratio for continuing CPAP is 13 (Table 3).

A number of patients had obstructive sleep apnea and coexisting COPD requiring therapy (n = 110, 10%). We have analyzed the effect of coexisting COPD on CPAP compliance. Of those patients refusing CPAP treatment, seven (13%) had coexisting COPD and there was no difference in CPAP acceptance rate between patients with COPD and other patients ($p = 0.3$). In the univariate analysis there was an odds ratio of discontinuing CPAP of 1.6 at a significance level of 0.01 for patients with COPD. The multivariate analysis showed no independent influence from COPD ($p > 0.2$).

Most of the patients with COPD had mild to moderate disease and only eight of those started on CPAP had coexisting chronic respiratory failure (defined as a Pa_{CO_2} greater than 45 mm Hg or a Pa_{O_2} less than 60 mm Hg). Some of these eight have been subsequently transferred to bilevel positive airway pressure, and this has been allowed for by the use of "censored" variables in our survival analyses. Bilevel treatment has not been analyzed in this study.

The significant determinants of the number of hours per night that CPAP was used were increasing AHI ($p = 0.004$), BMI ($p = 0.004$), Epworth score ($p = 0.046$), and age ($p = 0.03$). There was no difference in CPAP use rate between those diagnosed by polysomnography and limited sleep studies ($p > 0.5$).

DISCUSSION

This large follow-up study with a high rate of ascertainment shows that continuing CPAP usage is related to the severity of subjective sleepiness and to the apnea plus hypopnea frequency. Continuing CPAP usage at 3 yr occurred in 86% of patients with an AHI ⩾ 30 and an Epworth sleepiness rating of > 10. Our previous studies have shown that patients with mild SAHS and AHI between 5 and 15/h benefit from treatment (22), but this study showed that many such patients abandon CPAP, especially if they are not "subjectively" sleepy. Further, long-term use can be predicted most reliably by the average nightly use of the CPAP machine during the first 3 mo. The study also showed that patients using CPAP for less than 2 h per night at 3 mo are unlikely to continue with long-term treatment. Overall CPAP use in those taking CPAP home was 68% at 5 yr. Patients continued to abandon CPAP during the first 4 to 5 yr of treatment, in contrast to our clinical impression that those who continued using CPAP after the first few months tended to use it long-term. Although patients are less likely to abandon CPAP the longer they have been using it, many (n = 63; 29%) stop the treatment after 1 yr. Similarly, Krieger and colleagues (17) found that 20% of those who stop treatment do so after 1 yr.

In the analysis of continued use the outcome of interest is deliberate stopping of CPAP treatment and includes stopping because the patient abandoned treatment (15.5%) or because the machine was reclaimed for reasons of poor compliance or serious side effects. CPAP machines were reclaimed on 50 occasions (4.5%). Patients were warned about their poor use with the threat of having their machine reclaimed if use did not improve. This threat led to improved use in some patients, whereas others remained unwilling to increase use. The choice of 2 h as a cutoff is a somewhat arbitrary value as there is no known lower limit of average nightly use below which CPAP is ineffective (17, 22, 23). Kribbs and colleagues (16) used a criterion of minimal acceptable duration of use as at least 4 h use per night on ⩾ 70% of nights monitored. This equates to an average nightly use figure of 2.8 h. Krieger and colleagues

TABLE 3

MULTIVARIATE ANALYSIS: INDEPENDENT VARIABLES INFLUENCING CONTINUED CPAP USE

	Hazard Ratio*	95% CI†	p Value
AHI < 15 versus AHI ⩾ 15	2.48	1.79–3.46	< 0.001
Epworth ⩽ 10 versus Epworth > 10	1.92	1.41–2.61	< 0.001
Nonsnorer versus snorer	2.76	1.29–5.95	0.009
CPAP use at 3 mo < 2 h versus ⩾ 2 h	13.8	8.86–21.5	< 0.001

For definition of abbreviations, *see* Table 1.
* Relative risk of stopping CPAP.
† 95% confidence interval.

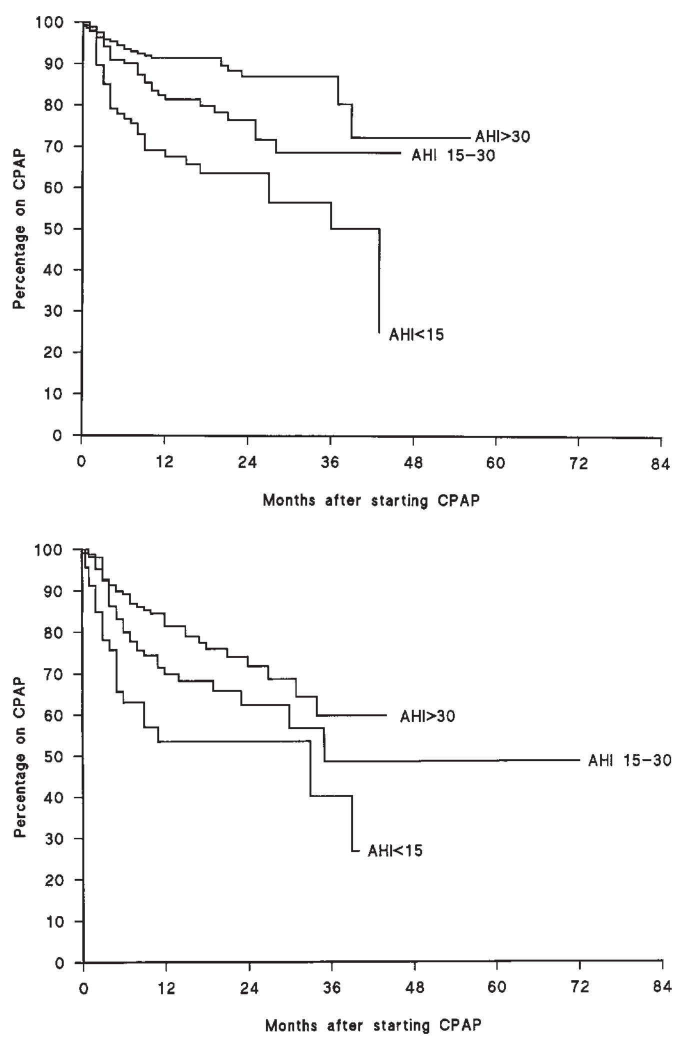

Figure 2. (*Top panel*) patients with Epworth score > 10 and varying AHI: percentage using CPAP versus time. (*Bottom panel*) patients with Epworth score ⩽ 10 and varying AHI: percentage using CPAP versus time.

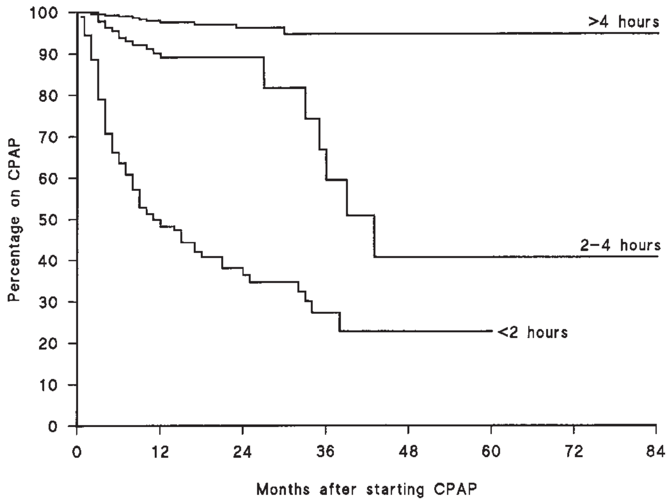

Figure 3. Percentage using CPAP versus time with varying average nightly CPAP run time at first follow-up visit (always ⩽ 3 mo).

(17) used a 1-h cutoff (after attempts to improve compliance) for withdrawal of CPAP treatment.

A number of smaller studies, some using only subjective reports of CPAP use (24, 25), have attempted to establish the important determinants of long-term CPAP usage with variable results (14, 17, 24, 25). Our results confirm that the severity of breathing abnormality during sleep (14, 17) and the degree of subjective sleepiness (24, 25) are predictors of continued CPAP use and shows that age, arousals, BMI, coexistence of COPD, and CPAP pressure are also relevant factors. As a lack of snoring history was rarely found (2%) among our patients this is not a very helpful discriminator in routine clinical practice. The study also shows for the first time that AHI and Epworth sleepiness score are the independent predictors of long-term CPAP use. These predictors are relatively weak, as can be seen from their hazard ratios (Table 3), but they can be combined to give a better prediction (Figure 2).

We found that continued CPAP use was greater in patients with higher CPAP pressures. One might expect increased pressure would increase mouth leak and thus nasal symptoms (26), thus worsening compliance. Because CPAP pressure was not an independent predictor of continuing use, presumably the relationship between pressure and use resulted from covariance of CPAP pressure with AHI, which was an independent predictor of use. The 95th centile of CPAP pressure was 14.2 cm. We are unable to comment with confidence on the effects of pressure on compliance at high pressures (higher than 14 cm). Further, there was no significant correlation between the CPAP pressure used and mean nightly CPAP use ($p = 0.09$).

Lack of benefit and side effects from CPAP were cited by patients as the main reasons for stopping treatment. Although side effects are reported equally in compliant and noncompliant groups (25, 27), tolerance of these side effects may differ. Evidence for this view was found by Pepin and colleagues (27) as CPAP was considered to be noisier by patients with mild SAHS. It is probable that the balance of benefits to side effects from CPAP is important in determining continued CPAP use.

In contrast to baseline information, data on rates of CPAP use obtained within 3 mo of starting CPAP is strongly predictive of long-term use. Our findings extend those of Kribbs and colleagues (16) who found that the pattern of CPAP use during the first 3 mo is established in the first month for most patients. Although early rate of use data are predictive as a continuous variable, an arbitrary cutoff of 2 h per night will separate most long-term CPAP users from those who have stopped (Figure 3). The likelihood of stopping is much higher for those who at 3 mo use CPAP for less than 2 h per night than for those who use it for 2 h or more, with a hazard ratio of 13. Long-term use of CPAP occurs in only 22% of patients with early time clock readings less than 2 h compared with 78% of the remaining patients. The importance of early use data in predicting continuing CPAP use may mean that there is a window of opportunity, shortly after starting CPAP, to influence future compliance. Increased patient education and support may be one way in which this could be done as suggested by a number of studies showing improved compliance with more intensive educational strategies (28, 29). There may, however, be a number of patients who are unable to tolerate CPAP treatment and who will not continue using CPAP long-term. Early identification of these patients would be useful so that resources could be deployed elsewhere and alternative treatments tried instead.

Only 4.5% of patients refused CPAP treatment, less than the 15 to 50% reported by other investigators (17, 25, 30). In this study we used comprehensive pre-CPAP education. As the acceptance rate was better than that reported by others (17, 25), where there was unknown or limited pretreatment education, it is postulated that the education provided by our center may be a reason for the high acceptance rate found. Free CPAP provision could also be a factor in initial acceptance, but Rauscher and colleagues (30) offered CPAP free to unselected patients with AHI > 15 with an acceptance rate of only 50%. Thus, patient selection may be another important factor as all our patients had to be symptomatic to be offered CPAP. In this study and in another (25), some patients may have been advised to begin CPAP treatment in the clinic but refused, without therefore being booked for CPAP titration. The exact number of these patients remains unknown in this study; however, either N.J.D. or T.M. directly made the decision to offer CPAP in all patients, and this number was very small (estimate < 10 patients).

A higher number of female patients refusing CPAP treatment has not been reported by others (17, 25, 30), and the reason for this is unknown. Witnessed apneas may provoke a degree of anxiety in the patient about their disease that results in them persevering at least beyond a CPAP titration night. The finding that CPAP refusers were more often specialist-referred probably results from 38% of such patients being referred from ENT specialists, and many of these presented with snoring as the main complaint. Presumably, many such patients will be less concerned about their own symptoms, perhaps decreasing motivation for therapy (17, 24). CPAP refusers also drank less alcohol and were more often current smokers, but the reasons for these relationships are unclear.

The median average nightly use of CPAP determined from clocks built into the machine was 5.7 h in those who continue with CPAP therapy. No lower threshold for effectiveness of CPAP is known; however, Engleman and colleagues (31) were able to show improvements in objective daytime sleepiness, symptom scores, mood, and cognitive function in a group of consecutive patients with SAHS with an average CPAP use of 3.7 h per night. Seventy-six percent of our patients used their CPAP machine for an average of 3.7 h or more per night. The rates of use quoted above refer to time the machine is running, not time at the preset therapeutic pressure. These data are not known for most of our patients; however, a number of studies have shown that a correction factor of 0.9 will give a reasonable estimation of time at therapeutic mask pressure (13, 15, 16). As demonstrated by Kribbs and colleagues (16), average nightly CPAP use figures may result from a wide range of patterns of actual nightly use and do not indicate whether use has been regular or irregular.

Automatic CPAP titration using the Autoset was performed on 106 of the patients studied. Autoset CPAP titration produces an accurate assessment of the optimal CPAP pressure (32). All of the remaining patients (n = 1,105) had manual CPAP titrations. These two groups of patients were both predominantly male and similar in terms of age (median = 50 yr, Autoset versus 50 yr; manual), BMI (median = 30 versus 30.5), AHI (median = 32 versus 31), and Epworth score (median = 13 versus 12). Two of the patients receiving Autoset CPAP titration refused to take CPAP home. Kaplan-Meier survival plots of continued use were similar (log-rank test, p = 0.11) and the median CPAP run time at the last visit for those continuing CPAP was similar (5.0 versus 5.7 h). Thus, the patients titrated using Autoset were similar to those titrated manually and had similar compliance and are therefore included in the analysis.

One of the potential criticisms of this study is that it involved 46 comparisons. Therefore, by chance alone, two to three relationships would be expected to be significant at the 0.05 level, whereas 23 significant relationships were found. There is no universally accepted statistical solution to this problem, and most statisticians feel that the Bonferroni correction for multiple comparisons is an overly conservative approach for such correlational data. However, even if this were used, there are still significant univariate relations between continued CPAP use and age, BMI, Epworth score, AHI, symptoms of SAHS, and CPAP pressure, with the independent determinants being unchanged except that snoring history is no longer significant.

This study was conducted in a health care system where there was no treatment cost for the patient. Although cost is a potential determinant of compliance in systems where treatment is not free the available evidence suggests that it may not significantly affect continued use. Studies in cost-free systems of subjective continued use (12) and objective short-term use (13) had similar levels of use to those in the United States, arguing against a significant effect of cost. Furthermore, Rolfe and colleagues (24) assessed reasons for discontinuing CPAP treatment in Australia where patients were asked to buy their CPAP machine and cost was not commonly given as a reason for discontinuing CPAP treatment (six of 61 patients). It is therefore likely that most of the findings of this study are also applicable to health systems that involve costs to the patient for CPAP treatment.

The effects of a strongly supportive system on long-term use are uncertain. Waldhorn and colleagues (25) reported their findings of subjective compliance in a system with limited follow-up support ("A follow-up home visit was provided by a respiratory care company on initiation of home therapy"). They found 76% of patients starting CPAP were still using it at 14 mo, comparable to the 82% in our center at 14 mo. Hence, our findings on long-term use of CPAP may apply to centers with a less supportive system than our own.

Other limitations of this study include the failure to contact 4.6% of patients and uncertainty about the number of patients who declined a CPAP trial before it was ever booked. However, we believe that selection bias has been minimized by the availability of data from nearly all patients in the study group. Furthermore, the remaining patients do not appear to be different from the study group in important baseline determinants of CPAP use. All of the objective data used in the study were accrued prospectively, thus avoiding potential bias from retrospective evaluation of data.

Other limitations include the facts that the Epworth sleepiness scale has only been in use since 1991 (33), and objective data from in-built clocks were not available in the early years of the study (pre-1990), although patients were all subsequently changed over to these CPAP machines. There are only five patients who started CPAP before 1990 and then stopped before being changed to machines with built-in time clocks. We therefore have objective data on compliance on the vast majority of patients starting CPAP before 1990. In addition, as we successfully followed up only 281 patients at 3 yr and 61 patients beyond 5 yr, longer-term studies will be required in the future.

In conclusion, this study found that in a cost-free system, with comprehensive pre-CPAP education very few symptomatic patients refused CPAP treatment, and they were more often women, were more often specialist-referred, and less often had a history of witnessed apneas. Just over two thirds of patients who took CPAP home continued with CPAP at 5 yr, with a median nightly use of 5.7 h. Although AHI, subjective daytime sleepiness, and snoring history have an independent role in predicting long-term CPAP use, they are weak predictors and should not be used in isolation to determine who merits a trial of CPAP treatment. Early CPAP use data are strongly predictive of continuing use and may help decisions about perseverance with CPAP treatment and allow early identification of patients who might benefit from more intensive education and support. It also suggests (28) that efforts to improve CPAP compliance should be targeted to the initial 3 mo.

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.
2. Cheshire, K., H. M. Engleman, I. J. Deary, C. Shapiro, and N. J. Douglas. 1992. Factors impairing daytime performance in patients with sleep apnea/hypopnea syndrome. *Arch. Intern. Med.* 152:538–541.
3. Guilleminault, C., J. Van der Hoed, and M. M. Mitler. 1978. Clinical overview of the sleep apnea syndromes. Sleep apnea syndromes. 1–12.
4. Findley, L. J., M. E. Unverzagt, and P. M. Suratt. 1988. Automobile accidents involving patients with obstructive sleep apnea. *Am. Rev. Respir. Dis.* 138:337–340.
5. George, C. F., P. W. Nickerson, P. J. Hanly, T. W. Millar, and M. H. Kryger. 1987. Sleep apnea patients have more automobile accidents. *Lancet* 2:447.
6. Young, T., P. Peppard, M. Palta, K. M. Hla, L. Finn, B. Morgan, and J. Skatrud. 1997. Population-based study of sleep-disordered breathing as a risk factor for hypertension. *Arch. Intern. Med.* 157:1746–1752.
7. Sullivan, C. E., and F. G. Issa. 1985. Obstructive sleep apnea. *In* Clinics in Chest Medicine. 633–650.
8. Guilleminault, C., F. Blair Simmons, J. Motta, J. Cumminskey, M. Rosekind, J. S. Schroeder, and W. C. Dement. 1981. Obstructive sleep apnea syndrome and tracheostomy: long-term follow-up experience. *Arch. Intern. Med.* 141:985–988.
9. Sanders, M. H., C. A. Gruendl, and R. M. Rogers. 1986. Patient compliance with nasal CPAP therapy for sleep apnea. *Chest* 90:330–333.
10. Issa, F. G., L. V. Costas, M. Berthon-Jones, V. J. McAuley, J. Bruderer, and C. E. Sullivan. 1985. Nasal CPAP treatment for obstructive sleep apnea: long-term experience with 117 patients (abstract). *Am. Rev. Respir. Dis.* 13:A108.
11. McEvoy, R. D., and A. T. Thornton. 1984. Treatment of obstructive sleep apnea syndrome with nasal continuous positive airway pressure. *Sleep* 7:312–325.
12. Hoffstein, V., S. Viner, S. Mateika, and J. Conway. 1992. Treatment of obstructive sleep apnea with nasal continuous positive airway pressure. *Am. Rev. Respir. Dis.* 145:841–845.
13. Engleman, H. M., S. E. Martin, and N. J. Douglas. 1994. Compliance with CPAP therapy in patients with the sleep apnea/hypopnea syndrome. *Thorax* 49:263–266.
14. Meurice, J., P. Dore, J. Paquereau, J. P. Neau, P. Ingrand, J. Chavagnat,

and F. Patte. 1994. Predictive factors of long-term compliance with nasal continuous positive airway pressure treatment in sleep apnea syndrome. *Chest* 105:429–433.

15. Reeves-Hoche, M. K., R. Meek, and C. W. Zwillich. 1994. Nasal CPAP: an objective evaluation of patient compliance. *Am. J. Respir. Crit. Care Med.* 149:149–154.
16. Kribbs, N. B., A. I. Pack, L. R. Kline, P. Smith, A. Schwartz, N. Schubert, S. Redline, J. Henry, J. Getsy, and D. Dinges. 1993. Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea. *Am. Rev. Respir. Dis.* 147:887–895.
17. Krieger, J., D. Kurtz, C. Petiau, E. Sforza, and D. Trautmann. 1996. Long-term compliance with CPAP therapy in obstructive sleep apnea patients and in snorers. *Sleep* 19:S136–S143.
18. Whyte, K. F., M. B. Allen, A. A. Jeffrey, G. A. Gould, and N. J. Douglas. 1989. Clinical features of the sleep apnea/hypopnea syndrome. *Q.J.M.* 267:659–666.
19. Gould, G. A., K. F. Whyte, G. B. Rhind, M. A. Airlie, J. R. Calterall, C. M. Shapiro, and N. J. Douglas. 1988. The sleep hypopnea syndrome. *Am. Rev. Respir. Dis.* 137:895–898.
20. Altman, D. G. 1991. Practical Statistics for Medical Research. Chapman and Hall, London. 365–395.
21. Cox, D. R. 1972. Regression models and life tables. *J. R. Stat.* 34:187–220.
22. Engleman, H. M., S. E. Martin, and N. J. Douglas. 1997. Effect of CPAP therapy on daytime function in patients with mild sleep apnea/hypopnea syndrome. *Thorax* 52:114–119.
23. Pieters, Th., Ph. Collard, G. Aubert, M. Dury, P. Delguste, and D. Rodenstein. 1996. Acceptance and long-term compliance with nCPAP in patients with obstructive sleep apnea syndrome. *Eur. Respir. J.* 9: 939–944.
24. Rolfe, I., L. G. Olson, and N. A. Saunders. 1991. Long-term acceptance of continuous positive airways pressure in obstructive sleep apnea. *Am. J. Respir. Crit. Care Med.* 144:1130–1133.
25. Waldhorn, R. E., T. W. Herrick, M. C. Nguyen, A. E. O'Donnell, J. Sodero, and S. J. Potolicchio. 1990. Long-term compliance with nasal continuous positive airway pressure therapy of obstructive sleep apnea. *Chest* 97:33–38.
26. Richards, G. N., P. Cistulli, G. Ungar, M. Berthon-Jones, and C. E. Sullivan. 1996. Mouth leak with continuous positive airway pressure increases nasal resistance. *Am. J. Respir. Crit. Care Med.* 154:182–186.
27. Pepin, J. L., P. Leger, D. Veale, B. Langevin, D. Robert, and P. Levy. 1995. Side effects of nasal continuous positive airways pressure in sleep apnea syndrome. *Chest* 107:375–381.
28. Hoy, C. Y., M. Vennelle, R. N. Kingshott, H. M. Engleman, and N. J. Douglas. 1987. Can CPAP use be improved? (abstract). *Am. J. Respir. Crit. Care Med.* 155:A304.
29. Likar, L. L., T. M. Panciera, A. D. Erickson, and S. Rounds. 1997. Group education sessions and compliance with nasal CPAP therapy. *Chest* 111:1273–1277.
30. Rauscher, H., W. Popp, T. Wanke, and H. Zwick. 1991. Acceptance of CPAP therapy for sleep apnea. *Chest* 100:1019–1023.
31. Engleman, H. M., S. E. Martin, I. J. Deary, and N. J. Douglas. 1994. Effect of continuous positive airway pressure treatment on daytime function on sleep apnea/hypopnea syndrome. *Lancet* 343:572–575.
32. Fleury, B., D. Rakotonanahary, C. Hausser-Hauw, B. Lebeau, and Guilleninault. 1996. A laboratory validation study of the diagnostic mode of the autoset system for sleep-related respiratory disorders. *Sleep* 19: 502–505.
33. Johns, M. W. 1991. A new method for measuring daytime sleepiness: the Epworth Sleepiness Scale. *Sleep* 14:540–545.