ARTICLE

Adherence to and Effectiveness of Positive Airway Pressure Therapy in Children With Obstructive Sleep Apnea

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ABSTRACT

OBJECTIVES. Positive airway pressure therapy (PAP) is frequently used to treat children who have obstructive sleep apnea syndrome and do not respond to adenotonsillectomy. However, no studies have evaluated objectively adherence to PAP in children, and few studies have evaluated objectively the effectiveness of PAP. The objective of this study was to determine adherence and effectiveness of PAP (both continuous [CPAP] and bilevel [BPAP] pressure) in children with obstructive apnea.

METHODS. A prospective, multicenter study was performed of children who were randomly assigned in a double-blind manner to 6 months of CPAP versus BPAP. Adherence was measured objectively using the equipment's computerized output. Effectiveness was evaluated using polysomnography.

RESULTS. Twenty-nine children were studied. Approximately one third of children dropped out before 6 months. Of the 21 children for whom 6-month adherence data could be downloaded, the mean nightly use was 5.3 ± 2.5 (SD) hours. Parental assessment of PAP use considerably overestimated actual use. PAP was highly effective, with a reduction in the apnea hypopnea index from 27 ± 32 to 3 ± 5/hour, and an improvement in arterial oxygen saturation nadir from $77 \pm 17\%$ to $89 \pm 6\%$. Results were similar for children who received CPAP versus BPAP. Children also had a subjective improvement in daytime sleepiness.

CONCLUSIONS. Both CPAP and BPAP are highly efficacious in pediatric obstructive apnea. However, treatment with PAP is associated with a high dropout rate, and even in the adherent children, nightly use is suboptimal considering the long sleep hours in children.

THE OBSTRUCTIVE SLEEP apnea syndrome (OSAS) affects ~2% of children.[1] The pathogenesis of childhood OSAS is multifactorial. Contributing factors include anatomic narrowing (as a result of both soft tissue and craniofacial structure) and abnormal upper airway neuromotor control.[2] In most children with OSAS, the primary factor that leads to the upper airway obstruction is adenotonsillar hypertrophy, and OSAS can be treated effectively with tonsillectomy and adenoidectomy.[3] However, in a small number of children in whom additional anatomic factors (including obesity) or abnormal upper airway neuromotor tone is the predominant cause for OSAS, OSAS persists postoperatively.[4] In these children, continuous positive airway pressure (CPAP) is usually used as the second line of treatment.[5]

Although home CPAP use has been reported in >300 children of all ages,[5-7] it is not yet approved by the Food and Drug Administration (FDA) for use in children who weigh <30 kg. Furthermore, few studies have evaluated the effectiveness of positive airway pressure (PAP) therapy in children, and no prospective studies have evaluated objective measures of adherence in the pediatric age group. We therefore conducted a multicenter, prospective study of PAP therapy in children with OSAS. The objectives of this study were to assess objectively adherence to and effectiveness of PAP in children. In addition, we sought in a randomized, double-blinded manner to compare the adherence to and effectiveness of CPAP versus bilevel pressure (BPAP) in children with OSAS. We hypothesized that effectiveness would be similar but adherence would be improved with BPAP compared with CPAP, as a result of the lower airway pressure during exhalation, resulting in increased patient comfort. This study was previously reported in abstract form.[8]

METHODS

The study was a prospective, multicenter study performed at 3 pediatric sleep centers (Johns Hopkins Hospital, Children's Hospitals and Clinics of Minnesota and Childrens Hospital Los Angeles). Children who had OSAS and whose surgical treatment failed or who were not considered surgical candidates (because of either minimal adenotonsillar tissue or surgical contraindications) were eligible for entry. Patients were randomly assigned in a double-blind manner to either CPAP or BPAP. They underwent a baseline polysomnogram, followed by a PAP titration polysomnogram. A repeat polysomnogram was performed on PAP after 6 months of therapy. Adherence was assessed with a computerized usage meter. Changes in weight, height, BMI, and blood pressure (BP) were assessed. In addition, subjective assessments were obtained from the parents.

Written informed consent was obtained from the patients' parent/legal guardian. In addition, assent was obtained from children who were older than 5 years.

The study was approved by the Institutional Review Board at each of the participating institutions and was conducted under an Institutional Review Board–approved investigational device exemption.

Study Group

Patients who were aged 2 to 16 years, had newly diagnosed OSAS, and were candidates for PAP were eligible for the study. Children who were younger than 2 years and those with Down syndrome were excluded from the study because the standard of care at 1 of the participating centers was to provide formal behavioral therapy for these patients to enhance adherence.[9] Patients with pathologic central apnea or chronic respiratory failure were excluded because they would require BPAP. Patients who had received previous PAP treatment were excluded. All patients received standard medical care from a pediatric, board-certified sleep specialist, including therapy for treatable risk factors for OSAS, before study enrollment.

OSAS was diagnosed according to pediatric standards.[10] Patients had to meet at least 1 of the following criteria: (1) obstructive apnea hypopnea index (AHI) ≥5/hour (hypopnea defined as a ≥50% decrease in airflow of any duration associated with 4% desaturation and/or arousal; obstructive apneas scored if ≥2 respiratory cycles in duration); (2) arterial oxygen saturation (Sao_2) nadir ≤85%, (3) peak end-tidal Pco_2 ≥55 mm Hg, or (4) Sao_2 <92% for ≥10% of total sleep time (TST) and end-tidal Pco_2 ≥50 mm Hg for ≥10% TST. In addition, patients had to have at least 1 of the following symptoms or signs: (1) snoring and difficulty breathing during sleep, (2) failure to thrive (weight <5th percentile for age), (3) pulmonary hypertension, (4) excessive daytime sleepiness (school-aged children), or (5) symptoms of attention-deficit/hyperactivity disorder or other behavioral problems (school-aged children).

Baseline Assessment

Patients underwent baseline polysomnography (PSG) as part of their clinical assessment, according to standard pediatric recommendations.[10–12] Height, weight, and awake BP were measured. Care was taken to follow pediatric guidelines and use appropriately sized BP cuffs when measuring the BP.[13] A standardized questionnaire regarding symptoms was administered to the caregivers.

Subjective Assessment

During a standardized interview, parents were asked to assess subjectively their child's degree of sleepiness, temperament, and school performance. Some questions had a yes/no response, and others rated frequency of events (eg, never, once a week, 2–3 times a week, >3 times a week). Questions regarding sleepiness included the general question of whether the child was sleepy, as well as more specific questions to assess the frequency of the

child's falling asleep while watching television, at school (for children older than kindergarten level), and when active. The frequency of snoring, labored breathing at night, and enuresis (for children ≥6 years of age) was assessed. Yes/no questions included questions as to whether the child was irritable, was hyperactive, had age-appropriate behavior, and had delayed development. For school-aged children, parents were asked to rate the child's school performance as "above average (mainly A's and B's)," "average (mainly C's)," or "below average (mainly D's and F's)."

Institution of PAP Therapy

Children were given a mask and headgear without the PAP unit to practice wearing for 2 weeks while awake to help them habituate to the system. Each family also received a standardized behavioral instruction sheet.[9] After 2 weeks, the patient underwent an overnight laboratory titration study to determine the optimal pressure required. A standardized protocol that was based on previous clinical pediatric experience was used. The goal of the titration polysomnogram was to eliminate all obstructive apneas, desaturation, and hypercapnia at a level of pressure tolerated by the patient without excessive awakenings. The minimal CPAP/expiratory pressure (EPAP) that was provided by the study equipment was 3 cm H_2O. For patients who were randomly assigned to CPAP, PAP was started at 3 cm H_2O and was increased to 4 cm H_2O and then increased further in 2-cm H_2O increments as needed. For patients who were randomly assigned to BPAP, the aim was to keep a 6-cm H_2O difference between inspiratory and expiratory pressures. The patient was started on 4/3 (minimum) cm H_2O; pressure then was increased by 2-cm H_2O increments to 6/3, 8/3, 10/4, 12/6, 14/8, 16/10 cm H_2O, etc. Supplemental oxygen was added when the patient desaturated persistently to <92% in the absence of apnea, paradoxical breathing, or snoring.

After the titration study, the patient was provided with a VPAP II ST-A (ResMed, San Diego, CA) PAP machine, mask, headgear, and humidifier, free of charge, and the family was instructed on its use. This machine can provide either CPAP or BPAP. The patient, the patient's family, and all study physicians and coordinators were blinded as to the mode of therapy. Because patients and their families were naïve to the use of PAP and had not experienced either CPAP or BPAP treatment in the past, it was not anticipated that they would guess which modality they were receiving. By necessity, the sleep technician was unblinded; however, the technician followed a strict protocol. Randomization was performed using a randomization table generated by the study sponsor, and numbered slips in envelopes were provided for each patient. The sleep technician set the equipment to the randomized mode during the titration polysomnogram. For preservation of blinding, the machine control panel and display were covered. Because few pediatric masks are available in the United States, a variety of masks were used to provide the best fit. For maximization of comfort and, hence, adherence, all patients were provided with a heated humidifier, and a 20-minute pressure ramp was used at sleep onset and after awakenings. After the sleep study, patients took the equipment home and were instructed to use it during all hours of sleep.

Follow-up

Patients received a follow-up telephone call after 48 hours and again after 1 week of PAP use. They then were seen in clinic every other month and received a telephone call on alternate months when they were not being seen. During clinic visits, the patient was assessed clinically; a standardized questionnaire regarding symptoms of OSAS, as well as side effects of positive pressure use, was administered; weight, height, and BP were measured; the equipment was inspected; and the usage meter was downloaded. During telephone calls, a standardized verbal questionnaire was administered regarding subjective symptoms as well as potential PAP problems and side effects. Side effects were assessed and treated at the discretion of the sleep specialist as per standard clinical practice (eg, prescribing nasal steroids for nasal congestion). After 6 months, a repeat polysomnogram was performed on current PAP settings; and height, weight, BP, and subjective complaints were reevaluated.

Patients who did not return for follow-up received telephone calls followed by letters. Patients who did not return their equipment also received registered letters.

Assessment of Adherence

Objective adherence was obtained by downloading the equipment at each clinic visit. Poor adherence was defined arbitrarily as use of PAP for an average of <3 hours/night. Patients with poor adherence received appropriate counseling and troubleshooting as per standard clinical practice. The protocol called for patients who were nonadherent at the 3-month evaluation to be switched to the alternative mode of therapy, with a repeat titration sleep study to ensure adequate ventilation. In practice, only 1 patient was switched to the other arm of the study, because most nonadherent patients were also not adherent with repeat visits. Patients who were lost to follow-up were assumed to be nonadherent.

Statistical Analysis

The primary objectives in this study were to determine adherence to and effectiveness of PAP, both CPAP and BPAP, in children with OSAS. The main outcome measurements were mean nightly hours of use and AHI. For continuous variables, such as age, values are given as means ± SDs.

For categorical variables, such as gender, the proportion of patients in each category is presented. Differences between the 2 modes (BPAP vs CPAP) for demographics (gender, race, and age) and baseline characteristics (height, weight, BP, and reason for OSA) were compared using the independent t test or χ^2 test where appropriate. These same types of analyses were done to determine differences in the adherent versus nonadherent groups. Differences between initial visit and end visit (5 month or 6 month) for outcome variables were assessed using paired t tests, χ^2 test, or Pearson correlation coefficients. Statistical significance required $P < .05$.

During the interim analyses, comparisons between modes were performed by 2-way analysis of variance with daily and monthly usage as a within-subjects factor and with mode as a between-subjects factor. There did not seem to be any differences between the BPAP and CPAP modes, so future analyses used combined data (CPAP + BPAP).

Data that were collected in this study were documented on case report forms. A Code of Federal Regulations Part 11 compliant database system was created using Microsoft Access 97 software (Redmond, WA) for computer entry and verification of the data collected on the case report forms. All computations of results were generated using SAS software (Version 8.2; SAS Institute, Cary, NC).

RESULTS

Study Group

Thirty children were enrolled. One patient who was randomly assigned to BPAP was excluded later because it was unclear whether his equipment was used or not, because there was a technical problem with the usage meter as a result of electricity surges in the home. Thus, the results from 29 patients are included in this article. Sixteen patient were randomly assigned to BPAP, and 13 were assigned to CPAP. Seven children weighed <30 kg, the FDA cutoff for PAP use. Study group details are shown in Table 1. OSAS was attributed to obesity in two thirds of the patients; 11 children weighed >100 kg (range: 12–171 kg).

For the CPAP group, the mean pressure used was 8 ± 3 cm H_2O (range: 4–12). For the BPAP group, the mean inspiratory pressure was 11 ± 4 cm H_2O (range: 4–16), and the mean EPAP was 5 ± 3 cm H_2O (range: 3–10).

Patient follow-up is shown in Fig 1. Nineteen patients completed all aspects of the protocol. Seven patients dropped out between 1 and 5 months of the study;

TABLE 1 Study Group Characteristics at Baseline

	BPAP (n = 16)	CPAP (n = 13)	t/χ^2 (DF)	P
Age, y				
Mean ± SD	10 ± 4	11 ± 4	$t = 0.91$ (27)	.37
Range	2–16	4–15		
Boys, n (%)	13 (81)	8 (62)	$\chi^2 = 1.40$ (1)	.24
Race, n (%)				.54
Black	7 (44)	8 (62)	$\chi^2 = 2.18$ (3)	
White	6 (38)	4 (31)		
Asian	2 (13)	0 (0)		
Hispanic	1 (6)	1 (8)		
Diagnosis, n (%)				.71
Obesity[a]	12 (75)	7 (54)	$\chi^2 = 2.13$ (4)	
Idiopathic status postadenotonsillectomy	2 (13)	3 (23)		
Craniofacial anomaly[b]	1 (6)	2 (15)		
Other[c]	1 (6)	1 (8)		
Height, cm				
Mean ± SD	138 ± 28	152 ± 26	$t = 1.40$ (27)	.17
z score	−0.15 ± 2.13	0.63 ± 1.62	$t = 1.09$ (27)	.29
Weight, kg				
Mean ± SD	68 ± 44	87 ± 53	$t = 1.06$ (27)	.30
z score	1.84 ± 1.78	2.34 ± 1.51	$t = 0.81$ (27)	.42
BMI, kg/m²				
Mean ± SD	31.2 ± 11.7	33.8 ± 13.7	$t = 0.56$ (27)	.58
z score	2.00 ± 1.15	2.19 ± 1.01	$t = 0.48$ (27)	.63
Systolic BP >95th percentile, n (%)[d]	5 (31)	5 (42)	$\chi^2 = 0.32$ (1)	.57
Diastolic BP > 95th percentile, n (%)[d]	1 (6)	1 (8)	$\chi^2 = 0.04$ (1)	.83

There were no significant differences in any of the parameters between the 2 groups. DF indicates degrees of freedom.

[a] One obese patient also had achondroplasia but was classified primarily as obese because he presented only at 16 years of age, and his BMI was >3 z scores. Another obese child had congenital adrenal hyperplasia.
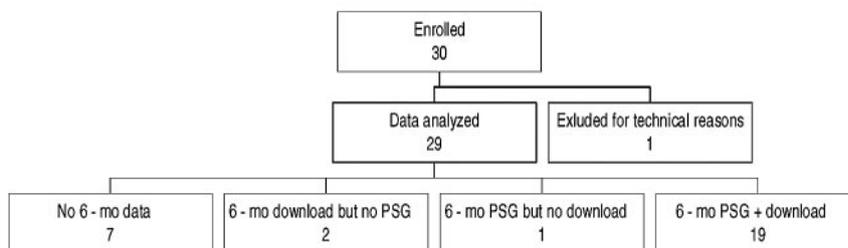
[b] Treacher-Collins syndrome; Towne-Brock syndrome; Stickler syndrome

[c] One Hurler syndrome; 1 status postrenal transplantation, reason for OSAS unclear.

[d] BP data were unavailable for 1 patient.

FIGURE 1
Flow diagram of patient enrollment and follow-up.

therefore, 6-month data were unavailable. Two patients had 6-month downloads but no PSG, and 1 had 6-month PSG but no download. There were no significant differences in baseline polysomnographic parameters between patients who completed the study and those who dropped out.

Adherence

Patients were classified as nonadherent when mean use was <3 hours/night, despite counseling and troubleshooting. In addition, patients who did not return for follow-up visits (despite frequent telephone calls and reminder letters) were classified as nonadherent; it was assumed that these patients were not using the equipment. Of the 8 patients who did not have 6-month downloads, 2 had 0 follow-up after initially receiving their equipment, despite concerted efforts to contact them. Of the remaining 6 patients, 4 used their machine for a mean of <1 hour/night in the month before dropping out, and 1 patient used it for 0, 2, and 5 hours, respectively, for the 3 months before he dropped out. Thus, it seems as though all of these dropouts were nonadherent. The last child was an exception, using the equipment for 4 to 7 hours/night for 5 months. After month 5, the child was placed out of the family and could not be located for follow-up. For the purpose of analysis, this patient was classified as nonadherent.

Mean nightly use is shown in Fig 2. Figure 2A shows the group mean hour use per month for all patients for whom hour meter readings were obtained; Fig 2B shows the hour use for all patients, assuming 0 hours for those for whom a download could not be obtained. At month 6, the mean nightly use for patients for whom downloads could be obtained was 5.3 ± 2.5 hours. The mean nightly use for all 29 patients, assuming that those who did not return to have their equipment downloaded were using the machines for 0 hours/night, was 3.8 ± 3.3 hours. Interindividual use was variable, with 3 children using their equipment for 9 to 10 hours/night. Among those who used the equipment for >3 hours a night, PAP use increased from month 1 to month 6 ($P = .008$).

There was no difference in use between patients who were using CPAP and BPAP (Fig 2), although the study was not powered to detect a difference between the 2

groups. It was assumed that a difference of 1 hour of use per night between the 2 treatment groups would be clinically significant. On the basis of an acceptable difference of 1 hour and an SD of 2.45 (the pooled SD), a sample size of 63 patients per group would have been required to provide a power of 80% at the 95% confidence level; this sample size was not practical for the current study.

There was no significant difference in age, gender, race, severity of OSAS (based on AHI, arousal index, and Sao_2 nadir), subjective symptoms (eg, sleepiness, enuresis, hyperactivity, irritability, school performance), mode of PAP, pressure level, or indication for PAP (obesity vs all other indications) between those who were nonadherent and those who were adherent.

Subjectively, parents were asked to estimate how many hours per night their child used the PAP. At the 5-month telephone call, 18 parents gave an estimated duration of use and had their equipment downloaded. Parents stated that their child used the PAP a mean of 7.6 ± 2.6 hours/night, whereas actual adherence, as determined by the usage meter, was 5.8 ± 2.4 hours ($P < .001$). However, 78% of parents admitted that their child did not use the machine every night. It was frequently volunteered that the machine was not used during weekends or vacations.

Effectiveness

PSG on PAP after 6 months of treatment was compared with baseline PSG for the 20 patients who returned for 6-month PSG. Of those who did not return for 6-month PSG, 2 were totally lost to follow-up, with no downloads available; 3 were adherent with their equipment before dropout; and 4 were nonadherent.

Polysomnographic parameters at baseline (while breathing spontaneously) and after 6 months (while on PAP) are shown in Table 2 for the 20 patients who returned for the 6-month study. Because there were no differences in any parameter between CPAP and BPAP, combined data are shown. There was no significant change in sleep architecture (sleep efficiency and sleep stage distribution) on treatment. However, major improvements were shown in respiratory parameters, with highly significant improvements in both the AHI ($P = .003$; Fig 3) and the Sao_2 nadir ($P = .001$). At baseline,
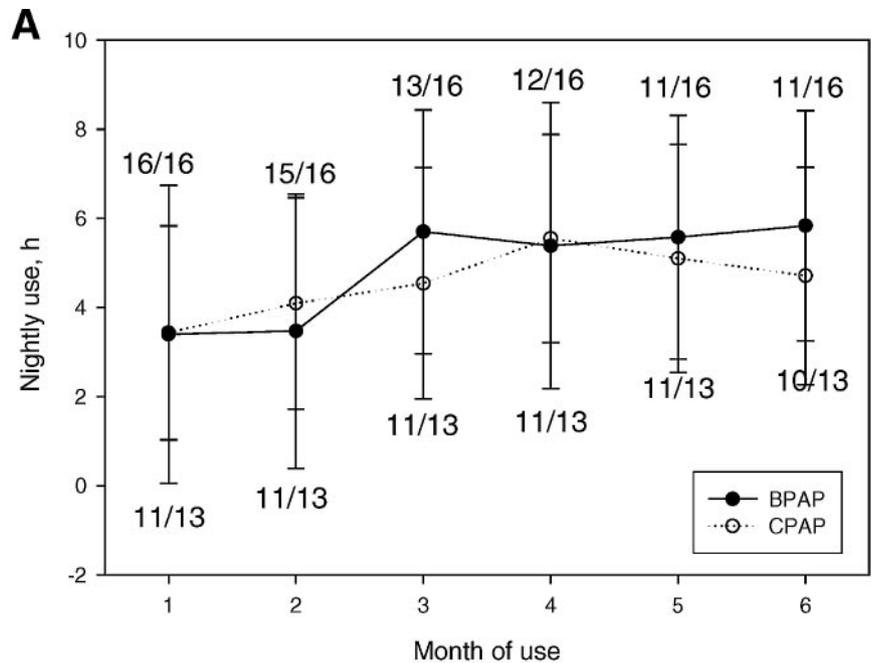
FIGURE 2

The mean (SD) nightly use is shown for patients who received CPAP (○) and BPAP (●). A, Data are shown only for patients for whom downloads could be obtained. The numbers above each data point reflect the number of patients who were using BPAP and for whom downloads could be obtained at that time point, over the number of patients who initially were enrolled. The numbers below each data point are the corresponding values for patients who were using CPAP. B, Data for all patients, assuming 0 usage for those for whom downloads could not be obtained. The tables show the *t* values, *P* values, and degrees of freedom for CPAP versus BPAP.

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
t	0.03	0.56	1.03	0.14	0.42	1.02
Degrees of freedom	25	24	21	21	20	19
P	.98	.58	.32	.89	.68	.32
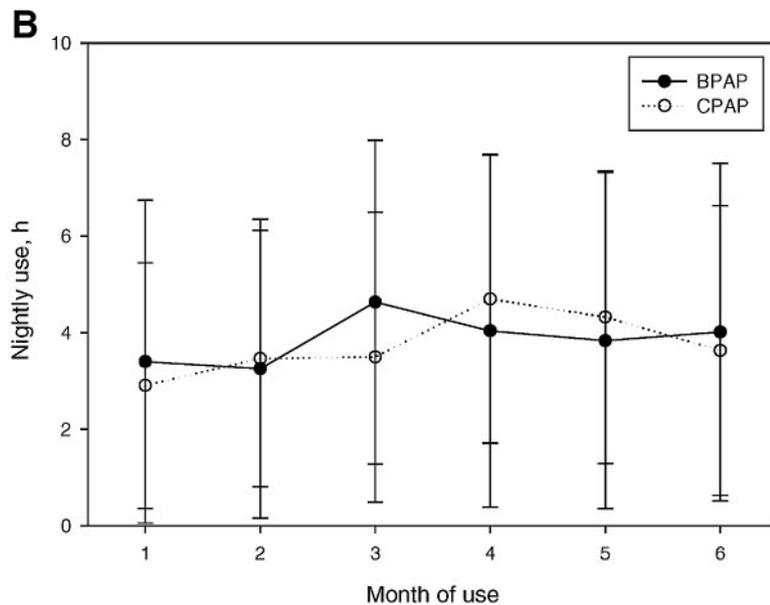
	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
t	0.44	0.19	0.95	0.52	0.39	0.32
Degrees of freedom	27	27	27	27	27	27
P	.66	.85	.35	.61	.70	.75

the AHI ranged from 3 to 115/hour, with 8 patients having an AHI >15/hour. On PAP, the AHI ranged from 0 to 17/hour, with only 1 patient having an AHI >15/hour. Two patients had a moderate increase in AHI; 1 from 8/hour to 12/hour, and the other from 12/hour to 17/hour. The reasons for this were unclear, but possibil-

TABLE 2 Polysomnographic Parameters

	Baseline	On PAP	t (DF)	P
Sleep efficiency, %	87 ± 8	85 ± 12	1.05 (19)	.31
Arousal index, n/h	17 ± 23	7 ± 2	1.85 (18)	.08
Rapid eye movement sleep, %TST	20 ± 6	21 ± 7	0.65 (17)	.52
Stage 1, %TST	6 ± 5	9 ± 23	0.47 (17)	.64
Stage 2, %TST	51 ± 17	53 ± 9	0.32 (17)	.75
Slow wave sleep, %TST	23 ± 14	23 ± 10	0.05 (17)	.96
AHI, n/h	27 ± 32	3 ± 5	3.44 (19)	.003
Central apnea index, n/h	1 ± 1	1 ± 2	0.53 (19)	.60
Mean Sao$_2$, %	95 ± 6	97 ± 2	1.87 (18)	.08
Sao$_2$ nadir, %	77 ± 17	89 ± 6	3.82 (19)	.001
Mean end-tidal CO$_2$ (mm Hg)	43 ± 5	44 ± 5	0.67 (14)	.52
Peak end-tidal CO$_2$ (mm Hg)	54 ± 4	53 ± 5	0.59 (15)	.56

Polysomnographic parameters at baseline and on PAP, after 6 months of home PAP, are shown for the 20 patients who returned for the 6-month polysomnogram. All data are displayed as mean ± SD. Accurate sleep staging could not be obtained in 2 children with developmental delay/neurologic abnormalities. There was a highly significant improvement in the AHI and Sao$_2$ nadir on treatment and a trend for an improvement in the arousal index and mean Sao$_2$.

ities include reduced TST during PSG for the first patient (216 minutes at baseline and 311 minutes at 6 months), which may have resulted in an inaccurate representation of the true AHI, and weight gain in the second patient (from 106 kg to 112 kg).

Growth
At baseline, most patients were of normal height (Table 1) but were overweight. The patients as a whole had a mean BMI z score of 2.1 ± 1.1. No patient had a weight or BMI z score <−1. Two patients had a height z score <−2, but both were obese, and the short stature was most likely related to their underlying disease (achondroplasia; renal transplant) rather than their OSAS. Six-month growth data were available for 20 patients. Growth parameters did not change significantly after 6 months of PAP. Only 1 obese patient lost weight (a 1.6-kg reduction from a baseline weight of 159 kg).

BP
Baseline BP data were available for 28 patients. At baseline, 36% of patients had a systolic BP >95th percentile for age, gender, and height; and 43% had a systolic BP >90th percentile. Seven percent had a diastolic BP >95th percentile, and 11% had a diastolic BP >90th percentile. Some but not all of these patient were obese, and 1 patient with systolic hypertension had a renal transplant and a longstanding history of hypertension on treatment. Six-month follow-up BP values were available for 18 patients. There was no significant difference in any of the BP parameters at 6 months.

Subjective Outcomes
After 6 months, there was a significant improvement in subjective parental assessment of sleepiness. This included an improvement in the number of children who were reported to be sleepy (P = .03), falling asleep while watching television (P = .004), and falling asleep at school (P = .007). Of note, at study entry, 58% of school-aged children were reported to fall asleep at school at least once a week, compared with only 6% after 6 months of PAP. However, there was no significant subjective improvement in age-appropriate behavior, delayed development, irritability, hyperactivity, enuresis, or reported school performance.

At baseline, 100% of parents reported that their children snored most nights (>3 nights a week). After 6 months of PAP, there was a significant improvement in reported snoring on PAP (P < .0001): 11% reported snoring most nights, 26% reported snoring some nights (<3 nights a week), and 63% reported no snoring. Similarly, there was an improvement in those who were reported to have difficulty breathing during sleep. At baseline, 62% of patients were reported to have frequent difficulty breathing during sleep, 34% had occasional difficulty breathing, and 3% were not observed to have difficulty breathing; at 6 months, the corresponding values were 5%, 16%, and 79% (P < .0001).

Side Effects and Technical Problems
Side effects and equipment problems were assessed by telephone interview soon after PAP was initiated (ie, at 48 hours) and after long-term use (5 months). After 48 hours of use, 14% of families complained of problems with the equipment (eg, equipment kept shutting off; confusion regarding setup) and 21% complained of problems with the mask (eg, "bubble" buckling, mask leaks). After 5 months, 10% of families complained of equipment problems (eg, tubing worn out) and 10% complained of occasional mask problems, primarily leaks. One of these families stated that the child had "pink eye," which may have been secondary to the mask leak.

Despite the use of heated humidification, nasal symptoms were common, occurring in 17% of patients at 48 hours and 38% of patients at 5 months. Nasal symptoms included congestion, rhinorrhea, and 2 cases of recurrent epistaxis. Of note, nasal symptoms at 5 months were significantly more common in those who were using CPAP than in those who were using BPAP (P = .02), although there was no difference between the 2 groups at 48 hours (P = .31).

Other side effects were rare. At 48 hours, 3% of families noted skin erythema related to the mask; and at 5 months, 10% noted erythema. However, in all cases, the erythema was only occasional and was transient in nature. One patient complained of acne in the mask distribution and 1 of irritation beneath the nose.

DISCUSSION
Although not approved by the FDA, the use of PAP in the pediatric population is increasing.[5–7,14–17] Nevertheless, few studies have evaluated its effectiveness in chil-

FIGURE 3
The AHI at baseline and on PAP after 6 months of therapy is shown for the 20 adherent patients. There was a significant decrease in AHI on PAP ($P = .003$, $t = 3.44$, degrees of freedom = 19).
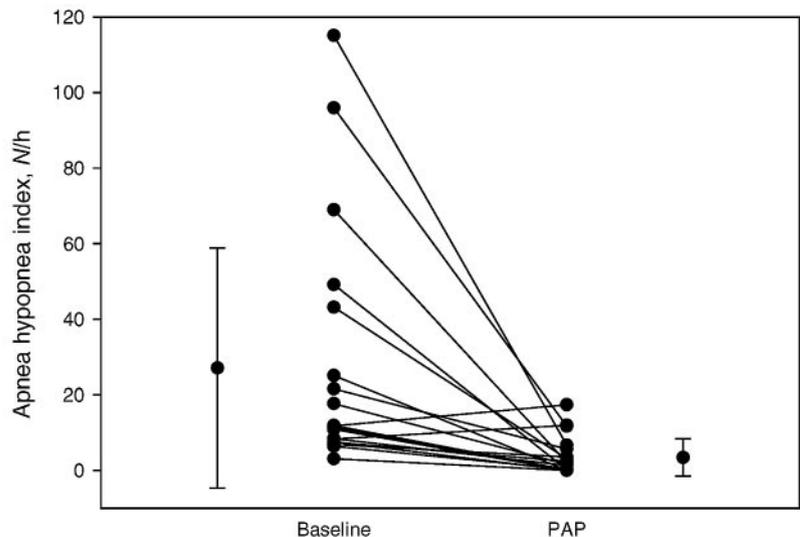
dren, and no other prospective studies have evaluated objectively adherence in children.

Adherence

The most important finding in this study was the relatively poor adherence. First, 8 patients dropped out of the study without providing final downloads. Two dropped out immediately, and no follow-up was obtained; it is unlikely that these patients used the equipment. Of the remaining dropouts, all but 1 had very low nightly use of their equipment before dropping out. The remaining child was placed out of the home and lost to follow-up. Thus, it is reasonable to assume that all but 1 of the dropouts stopped using their equipment. This is despite the fact that all patients received intensive support at a level greater than typically provided in the clinical situation. This support included the use of free equipment, including a ramp option and heated humidification, and frequent telephonic and clinic follow-up, where problems and side effects were addressed by pediatric sleep specialists. Second, those who continued to use the equipment used it only for a mean of 5.3 hours/night. Although this is very similar to adherence rates in adults,[18–21] children sleep longer than adults and thus would require longer PAP use. For the age range of 2 to 16 years, children sleep an average of 8 hours/night.[22]

In this study, we arbitrarily chose a cutoff of 3 hours of use a night to define adherence to evaluate the potential predictors of adherence. Clearly, 3 hours of use is suboptimal. However, as no previous studies have documented objective PAP use in children, we chose a low number that would clearly separate those who were using the equipment little if at all from those who were using it more consistently. There were no trends suggesting that a different cutoff point would yield different results.

Previous studies in children have reported relatively good rates of subjective adherence on the basis of parental report.[5,15] However, in this study, there was a marked discrepancy between parents' report of PAP use and objective adherence. Thus, it is important to monitor adherence objectively.

We found no difference in adherence or effectiveness between the two modes of pressure delivery. It should be noted that this study was not powered to detect a statistically significant difference. Nevertheless, there was no indication of a trend toward a difference in any of the parameters, although the mean CPAP pressures (8 cm H_2O) were higher than the mean EPAP pressures (5 cm H_2O). In adults, adherence has been shown to be similar between CPAP and BPAP use.[21] Nasal side effects after chronic use were more common in those who were using CPAP than BPAP. Future, larger studies to evaluate the difference in adherence between the 2 modes are required.

Two thirds of the patients in this study required PAP because of obesity. The prevalence of obesity is increasing rapidly in children and adolescents and is currently 15%.[23] Whereas in previous years OSAS in most children was related to adenotonsillar hypertrophy, it is now frequently related to obesity.[24] A significant number of children were extremely obese. Although not evaluated in this study, it is possible that these children had low self-esteem and other psychosocial issues related to their obesity that had an impact on their adherence with PAP.[25]

Effectiveness

Both CPAP and BPAP were highly effective at treating OSAS, as documented by the polysomnographic results. This is in agreement with several other studies that were performed in infants[16,17] and older children.[7,26,27]

No changes were seen in growth. This is in contrast to a large number of studies that demonstrated increased

weight and height after treatment of OSAS by tonsillectomy and adenoidectomy.[28–30] The difference between the current studies and the surgical studies is probably related to differences in the population. Most patients in our study had OSAS related to obesity rather than adenotonsillar hypertrophy, and the only 2 short patients (height z score ≥ 2 SD) had underlying diseases (achondroplasia, renal transplant) in which height would not be expected to improve. Unlike a previous report that evaluated the response to surgical treatment of OSAS,[31] the current study did not find an increase in obesity after PAP treatment.

A surprisingly large proportion of patients had systolic hypertension before institution of PAP. BP did not improve during this study. It is likely that the hypertension was attributable to obesity rather than OSAS, especially because diastolic hypertension may be more common than systolic hypertension in children with OSAS.[32]

Subjectively, parents noted an improvement in snoring and nocturnal breathing and an improvement in all parameters of daytime sleepiness, although they did not note any changes in temperament, hyperactivity, or school performance. Side effects were minor, although nasal symptoms were frequent.

Midfacial hypoplasia has been reported as a side effect of PAP in children, although it is probably rare.[33,34] We did not see any instances of this in the current study, but this may have been because infants were excluded from the study and because the study duration (6 months) may have been too short for this development to occur.

Limitations

The main limitation of this study was the high dropout rate. However, we posit that the dropouts, with the exception of 1 child who was placed out of the home, actually reflect nonadherence and thus are part of the outcome data for this study.

This study did not include an untreated control group. Theoretically, therefore, the study results (especially the subjective results) may have been attributable to a placebo effect. However, we consider it unlikely that all of the observed changes were attributable to a placebo effect because of the highly significant improvement in objective measurements such as the polysomnographic parameters. Previous studies that evaluated the effects of placebo (sham CPAP) in adults showed that placebo may cause a slight improvement in subjective measures such as quality-of-life parameters[35] but does not result in an improvement in measures of sleep-disordered breathing.[35,36]

CONCLUSION

We have shown that PAP treatment is effective in children with OSAS. However, adherence is an important issue. We found a high dropout rate and a suboptimal nightly usage in those who did not drop out. This is in contrast to previous pediatric studies that did not use objective adherence monitoring and contradicts parental reports regarding PAP use. We recommend that objective adherence monitoring be performed in all children who require PAP. Additional research is needed to develop methods to improve adherence in children who require PAP and to develop other treatment alternatives for children who do not respond to tonsillectomy and adenoidectomy and are unable to tolerate CPAP.

REFERENCES

1. Redline S, Tishler PV, Schluchter M, Aylor J, Clark K, Graham G. Risk factors for sleep-disordered breathing in children. Associations with obesity, race, and respiratory problems. *Am J Respir Crit Care Med.* 1999;159:1527–1532
2. Marcus CL, Katz ES, Lutz J, Black CA, Galster P, Carson KA. Upper airway dynamic responses in children with the obstructive sleep apnea syndrome. *Pediatr Res.* 2005;57:99–107
3. Schechter MS. Technical report: diagnosis and management of childhood obstructive sleep apnea syndrome. *Pediatrics.* 2002;109(4). Available at: www.pediatrics.org/cgi/content/full/109/4/e69
4. Suen JS, Arnold JE, Brooks LJ. Adenotonsillectomy for treatment of obstructive sleep apnea in children. *Arch Otolaryngol Head Neck Surg.* 1995;121:525–530
5. Marcus CL, Ward SL, Mallory GB, et al. Use of nasal continuous positive airway pressure as treatment of childhood obstructive sleep apnea. *J Pediatr.* 1995;127:88–94
6. Guilleminault C, Pelayo R, Clerk A, Leger D, Bocian RC. Home nasal continuous positive airway pressure in infants with sleep-disordered breathing. *J Pediatr.* 1995;127:905–912
7. Waters KA, Everett FM, Bruderer JW, Sullivan CE. Obstructive sleep apnea: the use of nasal CPAP in 80 children. *Am J Respir Crit Care Med.* 1995;152:780–785
8. Marcus CL, Davidson Ward SL, Lutz JM, Bolduc DB, Rosen G. Compliance with CPAP vs bilevel pressure in children. *Am J Respir Crit Care Med.* 2004;169:A732
9. Koontz KL, Slifer KJ, Cataldo MD, Marcus CL. Improving pediatric compliance with positive airway pressure therapy: the impact of behavioral intervention. *Sleep.* 2003;26:1010–1015
10. Rechtschaffen A, Kales A. *A Manual of Standardized Terminology: Techniques and Scoring Systems for Sleep Stages of Human Subjects.* Bethesda, MD: NINDB Neurological Information Network; 1968
11. American Thoracic Society. Standards and indications for cardiopulmonary sleep studies in children. *Am J Respir Crit Care Med.* 1996;153:866–878
12. American Sleep Disorders Association. EEG arousals: scoring rules and examples. *Sleep.* 1992;15:173–184
13. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics.* 2004;114(suppl 4th Report):555–576

14. Rains JC. Treatment of obstructive sleep apnea in pediatric patients. *Clin Pediatr.* 1995;34:535–541

15. Massa F, Gonsalez S, Laverty A, Wallis C, Lane R. The use of nasal continuous positive airway pressure to treat obstructive sleep apnoea. *Arch Dis Child.* 2002;87:438–443

16. McNamara F, Sullivan CE. Obstructive sleep apnea in infants and its management with nasal continuous positive airway pressure. *Chest.* 1999;116:10–16

17. Downey R III, Perkin RM, MacQuarrie J. Nasal continuous positive airway pressure use in children with obstructive sleep apnea younger than 2 years of age. *Chest.* 2000;117:1608–1612

18. 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

19. Reeves-Hoche MK, Meck R, Zwillich CW. Nasal CPAP: an objective evaluation of patient compliance. *Am J Respir Crit Care Med.* 1994;149:149–154

20. Krieger J, Kurtz D, Petiau C, Sforza E, Trautmann D. Long-term compliance with CPAP therapy in obstructive sleep apnea patients and in snorers. *Sleep.* 1996;19(suppl):S136–S433

21. Reeves-Hoche MK, Hudgel DW, Meck R, Witteman R, Ross A, Zwillich CW. Continuous versus bilevel positive airway pressure for obstructive sleep apnea. *Am J Respir Crit Care Med.* 1995;151:443–449

22. Iglowstein I, Jenni OG, Molinari L, Largo RH. Sleep duration from infancy to adolescence: reference values and generational trends. *Pediatrics.* 2003;111:302–307

23. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *JAMA.* 2002;288:1728–1732

24. Kelly A, Marcus CL. Childhood obesity, inflammation, and apnea: what is the future for our children? *Am J Respir Crit Care Med.* 2005;171:202–203

25. Banis HT, Varni JW, Wallander JL, et al. Psychological and social adjustment of obese children and their families. *Child Care Health Dev.* 1988;14:157–173

26. Guilleminault C, Nino-Murcia G, Heldt G, Baldwin R, Hutchinson D. Alternative treatment to tracheostomy in obstructive sleep apnea syndrome: nasal continuous positive airway pressure in young children. *Pediatrics.* 1986;78:797–802

27. Palombini L, Pelayo R, Guilleminault C. Efficacy of automated continuous positive airway pressure in children with sleep-related breathing disorders in an attended setting. *Pediatrics.* 2004;113(5). Available at: www.pediatrics.org/cgi/content/full/113/5/e412

28. Marcus CL, Carroll JL, Koerner CB, Hamer A, Lutz J, Loughlin GM. Determinants of growth in children with the obstructive sleep apnea syndrome. *J Pediatr.* 1994;125:556–562

29. Bar A, Tarasiuk A, Segev Y, Phillip M, Tal A. The effect of adenotonsillectomy on serum insulin-like growth factor-I and growth in children with obstructive sleep apnea syndrome. *J Pediatr.* 1999;135:76–80

30. Williams EF III, Woo P, Miller R, Kellman RM. The effects of adenotonsillectomy on growth in young children. *Otolaryngol Head Neck Surg.* 1991;104:509–516

31. Soultan Z, Wadowski S, Rao M, Kravath RE. Effect of treating obstructive sleep apnea by tonsillectomy and/or adenoidectomy on obesity in children. *Arch Pediatr Adolesc Med.* 1999;153:33–37

32. Marcus CL, Greene MG, Carroll JL. Blood pressure in children with obstructive sleep apnea. *Am J Respir Crit Care Med.* 1998;157:1098–1103

33. Li KK, Riley RW, Guilleminault C. An unreported risk in the use of home nasal continuous positive airway pressure and home nasal ventilation in children: mid-face hypoplasia. *Chest.* 2000;117:916–918

34. Marcus CL. Ventilator management of abnormal breathing during sleep: continuous positive airway pressure (CPAP) and nocturnal noninvasive intermittent positive pressure ventilation. In: Loughlin GM, Carroll JL, Marcus CL, eds. *Sleep and Breathing in Children—A Developmental Approach.* New York, NY: Marcel Dekker; 2000:97–812

35. Marshall NS, Neill AM, Campbell AJ, Sheppard DS. Randomised controlled crossover trial of humidified continuous positive airway pressure in mild obstructive sleep apnoea. *Thorax.* 2005;60:427–432

36. 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

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