Outcomes of Pediatric Titration Sleep Studies Following Empirical Use of Positive Airway Pressure and the Effect on Adherence to Therapy

L Denise Willis, Beverly J Spray, April Scribner, Kristi Pruss, and Supriya Jambhekar

BACKGROUND: Obstructive sleep apnea (OSA) is diagnosed through polysomnography (PSG) testing and commonly treated with positive airway pressure (PAP). The initial recommended treatment for pediatric OSA is adenotonsillectomy, but when this is contraindicated or ineffective, PAP is the next option. Children followed in our pediatric sleep disorders center who are diagnosed with OSA and meet criteria for therapy are empirically prescribed a PAP device, usually auto-titrating PAP (APAP), to avoid delays in therapy. Titration PSG is performed later to assess adequacy of settings. The aims of this study were to determine how often PSG titration results in changes to empirically prescribed PAP and to assess adherence to therapy before and after PSG titration. METHODS: A retrospective medical records review was completed for children diagnosed with OSA, prescribed PAP, and had a titration PSG within a 5-y consecutive period of 2008–2012. Demographic data, type of device, pressure settings, and adherence downloads were reviewed. Adherence was assessed before and after titration overall and compared for those who did and did not have therapy changes following titration. RESULTS: The study included 121 participants. Median age at the time of the diagnostic PSG was 11 (interquartile range [IQR] 8–14) y. Most (106, 88%) were initially prescribed APAP. Median length of time between initial and follow-up PSG was 6.4 (IQR 4.4–10.1) months. The majority (94, 78%) had therapy changes following titration. Overall, adherence percentage > 4 h per night was not significantly increased post titration ($P = .47$). There were no statistically significant differences in adherence between those who had therapy changes and those who did not ($P = .26$). CONCLUSIONS: Titration studies resulted in therapy modifications for most children. Adherence was not increased following the titration PSG. Changes in therapy did not result in increased adherence. Titration PSGs may optimize empirically prescribed settings. *Key words: polysomnography; titration study; obstructive sleep apnea; pediatric; positive airway pressure; auto-titrating positive airway pressure; continuous positive airway pressure; bi-level positive airway pressure.* [Respir Care 2022;67(4):464–470. © 2022 Daedalus Enterprises]

Introduction

Obstructive sleep apnea (OSA) is characterized by recurrent partial or complete upper-airway obstruction during sleep, causing abnormal gas exchange and/or fragmented sleep.[1-3] The prevalence of pediatric OSA ranges from 1–5%.[2,3] Untreated OSA can lead to behavioral issues, cognitive deficits, impaired growth, depression, decreased quality of life, and severe complications including cardiovascular effects.[2,3] Diagnosis is made through clinical evaluation and polysomnography (PSG) testing.[1,3-5] Adenotonsillectomy is the recommended initial treatment for OSA in children, but when this is contraindicated or ineffective, the next option is usually a positive airway pressure (PAP) device.[1-3,6] This differs from adult OSA where PAP is considered the first treatment.[7]

PAP can be administered either as fixed CPAP, auto-titrating PAP (APAP), or bi-level PAP (BPAP) therapy. APAP devices employ algorithms to automatically adjust and titrate the pressure within the defined range for events such as snoring, apnea, hypopnea, and air flow limitation.[8-9] APAP is considered as effective as CPAP for treating OSA in adults.[10-15] Whereas commonly utilized for managing OSA in children, APAP has not been as extensively studied as compared to adults.[4,16-21] PAP is an effective treatment for OSA, but adherence to therapy is often inconsistent or poor for both adults and children.[22-25]

Following diagnosis of OSA through PSG testing, children followed in our practice who are candidates for PAP are prescribed therapy, usually APAP, with empirical settings. This approach is utilized to avoid treatment delays due to the wait period for PSG scheduling in our lab. Most

of these children are then enrolled in a multidisciplinary adherence program created to assist with adjusting to the device and improving adherence to therapy.[22] Mask fit is determined by the sleep clinic respiratory therapist and assessed at each follow-up visit. Adherence is evaluated at each visit by analysis of device download reports. Once children are considered desensitized to the equipment, a follow-up PSG is performed to titrate and assess adequacy of therapy settings.

Initiation of PAP therapy with empirical settings has been utilized in adults with improvement in OSA symptoms.[26] This approach may also assist with reducing delays in starting treatment.[8,16] The aim of this research study was to assess how often pediatric PSG titration studies result in changes to empirically prescribed PAP and the effect of therapy changes on adherence.

QUICK LOOK

Current knowledge

Positive airway pressure (PAP) therapy for treatment of obstructive sleep apnea is often initiated with empirical settings in adults. Titration polysomnography (PSG) studies are done to assess adequacy of settings. Adherence to PAP is influenced by several factors and is generally low. The relationship of PSG titration and therapy changes on adherence is unknown.

What this paper contributes to our knowledge

The majority of children had PAP modifications after a follow-up PSG. Titration PSG studies may optimize therapy settings. Adherence was not increased following titration or therapy changes. Modifications to therapy and subject age were not found to have an effect on adherence.

Methods

The study was approved by the institutional review board at the University of Arkansas for Medical Sciences. This was a retrospective review of medical records in the Sleep Disorders Center at Arkansas Children's Hospital in Little Rock, Arkansas. Inclusion criteria were children diagnosed with OSA through initial PSG testing, prescribed PAP therapy, and had a PSG titration study within a 5-y consecutive period of 2008–2012. Children with a tracheostomy or dependent on invasive mechanical ventilation were excluded. The primary outcome was identification of therapy modifications following PSG titration. The secondary outcome was adherence to therapy.

Collected data included demographics, body mass index (BMI), comorbidities, diagnostic and follow-up PSG, apnea-hypopnea index (AHI) and other sleep measures, type of device, PAP settings, and adherence. American Academy of Sleep Medicine criteria were used to score all PSGs.[27] Categorical data were expressed as a frequency and percentage. Summary statistics for continuous data were expressed as either mean ± SD or median and interquartile range (IQR), depending on the distribution.

Adherence was obtained from the device download report and included 2 measures: adherence > 4 h per night and total adherence. Adherence > 4 h was the percentage of nights therapy was used > 4 h a night.[22] Total adherence was reported as the percentage of all nights the device was used for any amount of time.

Adherence comparisons before and after follow-up PSG were evaluated for normality and equal variance. Subjects with missing pre- or post-adherence data were excluded from analysis. Initially, age was assessed as a covariate to determine if there was an association with adherence variables. There was no statistically significant association between age and adherence pre-to-post intervention.

Adherence at > 4 h was parametrically sound; therefore, a paired *t* test was performed to determine if differences existed from pre-to-post intervention. Data on total adherence was too strongly skewed for parametric statistics, so a Wilcoxon signed-rank test was performed to determine if before and after values differed. To assess whether the number of subjects differed by type of device from pre-to-post intervention, a chi-square test was conducted. Cohen *d* formula for a paired *t* test was used to estimate the effect size for before and after adherence findings. Statistical significance was set at $P \leq .05$. Data analyses were conducted in SAS software, version 9.4 (SAS Institute, Cary, North Carolina).

Results

The study included 121 subjects of whom the majority were male (77, 64%), white (68, 56%), and non-Hispanic

Mss Willis, Scribner, and Pruss are affiliated with Respiratory Care Services, Arkansas Children's Hospital, Little Rock, Arkansas. Dr Spray is affiliated with Arkansas Children's Research Institute, Little Rock, Arkansas. Dr Jambhekar is affiliated with Pulmonary and Sleep Medicine, Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, Arkansas.

Ms Willis serves as Section Editor for RESPIRATORY CARE. The authors have disclosed no other conflicts of interest.

Ms Scribner presented a version of this manuscript at SLEEP 2013: the 27th Annual Meeting of the Associated Professional Sleep Societies held in Baltimore, Maryland, June 1–5, 2013.

The study was performed at Arkansas Children's Hospital, Little Rock, Arkansas.

Correspondence: Supriya Jambhekar MD, 1 Children's Way, Slot 512–17, Little Rock, AR 72202. E-mail: JambhekarSupriya@uams.edu.

DOI: 10.4187/respcare.09521

Table 1. Demographic Characteristics

Demographic	Subjects, *n* (%)
Sex	
Female	44 (36)
Male	77 (64)
Race	
Black	49 (40)
Latino/Hispanic	3 (3)
Multiracial	1 (1)
White	68 (56)
Ethnicity	
Hispanic	3 (3)
Non-Hispanic	118 (97)

Table 2. Comorbidities

Comorbid Conditions	Subjects, *n* (%)
Obesity	74 (61)
Allergic rhinitis/allergies	28 (23)
Asthma	27 (22)
Down syndrome	20 (17)
Attention deficit disorder	18 (15)
Depression	15 (12)
Gastroesophageal reflux	14 (12)
Seizure disorder	9 (7)
Hypertension	9 (7)
Developmental delay	8 (7)
Asperger syndrome	6 (5)
Cardiac diagnoses	5 (4)
Neuromuscular disease	4 (3)
Cerebral palsy	4 (3)
Prader-Willi	4 (3)
Diabetes	4 (3)
Hypothyroidism	4 (3)
Unspecified behavioral issue	4 (3)
Anxiety	3 (2)
Upper-airway anomalies	3 (2)
Obsessive-compulsive disorder	3 (2)
Spina bifida	2 (2)
Adjustment disorder	2 (2)
Unspecified eating disorder	2 (2)
Other (1 subject each)	14 (12)
Goldenhar syndrome	
Bipolar disorder	
Crouzon syndrome	
Autism	
Strabismus	
Dysphagia	
Brain tumor	
Acanthosis nigricans	
Chromosome VI deletion	
Post-lung transplant	
Post-traumatic stress disorder	
Moyamoya disease	
Scoliosis	
Tuberous sclerosis	

(118, 97%). Refer to Table 1 for additional demographics. Median age at the time of the diagnostic PSG was 11 (IQR 8–14) y. The median BMI was 32 (IQR 21–41) kg/m^2. Most subjects (111, 92%) had comorbidities in addition to OSA, and several of those (89/111, 80%) had more than one comorbid condition. The most common comorbidities were obesity (74, 61%), allergic rhinitis and/or allergies (28, 23%), and asthma (27, 22%). A small number of subjects had behavioral health issues such as attention deficit disorder (18, 15%) or depression (15, 12%). All comorbidities are included in Table 2.

On the diagnostic PSG, the median AHI was 20.1 (IQR 11–34) events per h. Most had abnormal oxygenation and normal ventilation. Table 3 includes additional PSG details. The majority of children (106, 88%) was empirically prescribed APAP (105 auto-titrating CPAP, 1 auto-titrating BPAP). The remaining subjects (15, 12%) were prescribed fixed-pressure therapy devices (10 CPAP, 5 BPAP). BPAP was ordered rather than CPAP when there were issues with elevated CO_2. For those prescribed APAP, the mean minimum and maximum pressures were 5 ± 1 and 13 ± 3 cm H_2O, respectively. The single auto-titrating BPAP device settings were inspiratory PAP (IPAP) 10–16 cm H_2O and expiratory PAP (EPAP) 6–10 cm H_2O. The mean fixed CPAP pressure was 9.1 ± 1.4 cm H_2O. Mean fixed BPAP settings were IPAP 13 ± 3 cm H_2O and EPAP 6 ± 2 cm H_2O.

After PAP initiation, 117 (97%) subjects attended at least one clinic visit before the follow-up PSG. Adherence data obtained from the last visit prior to the follow-up PSG were reported for 113 (93%) subjects. The median adherence percentage for > 4 h per night was 72% (IQR 42–86). The median percentage of total nights used was 94% (IQR 78–97). Few subjects (16, 13%) had therapy changes prior to the follow-up PSG. Of those with modifications, most were adjustment to settings (12/16, 75%; 10 change in auto range settings, 2 fixed pressure increased), and the others were changes in device type (4/16, 25%; 2 changed from CPAP to APAP, 1 APAP to CPAP, 1 BPAP to CPAP).

The median length of time between the initial and follow-up PSG was 6.4 (IQR 4.4–10.1) months. The majority of children (94, 78%) had therapy changes following PSG titration. Most modifications were for change of device type (67, 55%), with many transitioning from APAP to CPAP (58, 48%). All other modifications were settings adjustments (27, 22%), primarily changes to the APAP range (20, 17%). The addition of supplemental oxygen was required for one subject who also had a change in device type. Table 4 includes additional information regarding specific device changes.

Most subjects were prescribed an APAP device after the initial PSG. Following the titration PSG, the majority was transitioned to fixed-pressure CPAP or BPAP devices (74,

Table 3. Diagnostic Polysomnography Results

Sleep Efficiency Percentage Median (IQR)	Arousal Index Events per h Median (IQR)	Abnormal Oxygenation *n* (%)	Lowest S_{pO_2}% Median (IQR)	% Sleep Time $S_{pO_2} < 90\%$ Median (IQR)	Abnormal Ventilation *n* (%)	Highest $ETCO_2$ mm Hg Median (IQR)	% Recorded CO_2 > 50 mm Hg Median (IQR)
88.7 (81.1–85.0)	25.3 (15.2–40.6)	82 (68)	83 (76–89)	0.15 (0.01–2.30)	42 (35)	54 (50–58)	1.6 (0–14.2)

IQR = interquartile range
$ETCO_2$ = end-tidal CO_2

Table 4. Changes Post-Titration Polysomnography

Type of Change	Subjects, *n* (%)
Change Device Type	67 (55)
APAP to fixed device	63 (52)
Auto CPAP to CPAP	58 (48)
APAP to BPAP	4 (3)
Auto BPAP to BPAP*	1 (< 1)
Fixed pressure to APAP	3 (2)
CPAP to APAP	2 (2)
BPAP to Auto BPAP	1 (< 1)
Change Auto Type	1 (< 1)
Auto CPAP to Auto BPAP	
Settings adjustments	27 (22)
Auto range	20 (17)
Increase CPAP	5 (4)
Increase BPAP	2 (2)

* Addition of supplemental oxygen.
APAP = auto-titrating PAP
BPAP = bi-level positive airway pressure

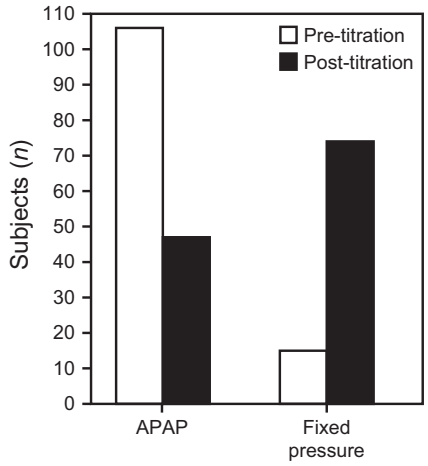

Fig. 1. The majority of children utilized APAP devices prior to polysomnography (PSG) titration but were changed to fixed-pressure devices after the follow-up PSG. APAP = auto-titrating positive airway pressure.

61%; chi-square = 61.9, $P < .001$). See Figure 1. Pressure settings for all devices were similar after the follow-up PSG. Table 5 presents the comparison of before and after titration settings.

A follow-up clinic appointment was attended by 107 (88%) subjects after PSG titration, and all had adherence downloads. Median adherence > 4 h per night was 76% (IQR 44–90), and total nights used was 93 % (IQR 75–97). Before and after titration paired adherence data were available for 101 (83%) subjects. The differences before and after titration were not significant for adherence > 4 h ($t = 0.72$, $P = .48$) but were for total adherence ($M = 18.5$, $P < .001$). The effect size was small; therefore, any differences were not clinically important. Table 6 includes additional details. There was no effect or association of subject age on either adherence measure.

A subgroup analysis compared adherence in subjects with and without therapy changes before and after titration. Paired data were available for 81 (81/94, 86%) subjects with therapy modifications and 20 (20/27, 74%) without changes. There was no significant difference in adherence > 4 h ($t = 1.13$, $P = .26$) or total nights used ($t = 0.34$, $P = .73$). See Table 7.

Discussion

In our practice, most children are prescribed an APAP device with empirical settings for initial treatment of OSA. We utilize this approach to avoid delays in treatment as there is typically a 4–6 month wait for PSG scheduling in our lab. Many are then followed in our Adherence Program for desensitization prior to a follow-up PSG for titration.[22] Some centers have indicated challenges with obtaining PAP equipment prior to titration due to third-party payer requirements. However, we have not encountered this when the diagnostic PSG meets criteria for diagnosis of OSA.

Follow-up titration studies resulted in both device changes and settings adjustments for the majority of subjects in our study. The most common modification was transition from APAP to a fixed-pressure device, and there were more children with fixed-pressure devices than APAP after the titration PSG. A previous study that evaluated

Table 5. Settings Comparison Before and After Titration Polysomnography

Device	Pre-Titration Settings X ± SD	Post-Titration Settings X ± SD
Auto-titrating CPAP	Minimum 5 ± 1 cm H_2O	Minimum 5.3 ± 1.4 cm H_2O
	Maximum 13 ± 3 cm H_20	Maximum 12.6 ± 2.6 cm H_20
Auto-titrating BPAP	IPAP 10–16 cm H_2O*	Minimum IPAP 9.0 ± 1.4 cm H_2O
	EPAP 6–10 cm H_2O*	Maximum IPAP 16.0 ± 2.8 cm H_2O
		Minimum EPAP 3.0 ± 1.4 cm H_2O
		Maximum EPAP 9.0 ± 1.4 cm H_2O
CPAP	9.1 ± 1.4 cm H_2O	9.8 ± 2.2 cm H_20
BPAP	IPAP 13 ± 3 cm H_2O	IPAP 13.5 ± 2.7 cm H_2O
	EPAP 6 ± 2 cm H_20	EPAP 8.6 ± 3.0 cm H_20

* Single device settings in lieu of X ± SD.
BPAP = bi-level positive airway pressure
IPAP = inspiratory positive airway pressure
EPAP = expiratory positive airway pressure

Table 6. Before and After Titration Adherence

Adherence Measure	Pre-Titration Median (IQR)	Post-Titration Median (IQR)	*P*	Effect Size*
Percentage > 4 h per night	75 (44–56)	77 (47–91)	.47	0.10
Percentage total all nights used	94 (82–97)	93 (75–97)	< .001	0.15

* Based on a Cohen *d* for paired data.
IQR = interquartile range

Table 7. Subgroup Adherence Comparison With and Without Therapy Changes

Adherence Measure	No-Change Group Pre-Titration *n* = 20 Median (IQR)	No-Change Group Post-Titration *n* = 20 Median (IQR)	Therapy Changes Group Pre-Titration *n* = 81 Median (IQR)	Therapy Change Group Post-Titration *n* = 81 Median (IQR)
Percentage > 4 h per night	60 (28–86)	68 (35–90)	75 (51–86)	77 (52–90)
Percentage total all nights used	91 (74–96)	91 (75–97)	95 (86–99)	93 (76–97)

IQR = interquartile range

variable versus fixed-pressure therapy in adults found no differences in patient preference of device.[28] Literature regarding device preference in children was not available.

After titration, the last clinic note and adherence report were evaluated along with follow-up PSG results. If the optimum pressure determined by the study did not fall in the range of APAP, or if the APAP pressure was too wide, then pressures were changed. Pressure changes were especially made if adherence was poor or if there were complaints about the PAP device. Change to a fixed device occurred when the 90th percentile pressure on the adherence download varied substantially from the optimum pressure determined on the sleep study or when the range of optimum pressure for different stages of sleep in different body positions was not distinct. This was done mainly when adherence was poor or there was no improvement in symptoms with PAP.

An evaluation of PSG titration in children requiring long-term CPAP and BPAP identified frequent settings changes following titration, and when changes were implemented, there was improvement in symptoms.[29] Most of the children in that study had other underlying diagnoses besides OSA such as neuromuscular disease or various syndromes. Another evaluation of PSG titration found an association between therapy changes and the length of time between therapy initiation and titration.[30] The authors concluded that changes were more likely if there was a shorter time from

the start of therapy to titration.[30] Whereas a few pediatric studies examined outcomes of titration studies, they did not assess the impact of therapy changes on adherence.

Adherence rates in children have been described as ranging from 30–60%.[31] A systematic review of adherence across age groups described factors including age, maternal education, and mask style as affecting adherence in children.[24] A recently published study by Blinder and colleagues found that older children with less severe sleep-disordered breathing were more apt to be non-adherent to PAP.[32] A study of PAP use in infants found comparable adherence rates to that of school-age children.[33] Hawkins et al[23] identified poor adherence in half the pediatric population they studied and that females and those with developmental delay were more likely to have good adherence to therapy. Higher maternal education and increased caregiver support have also been found to improve PAP adherence in children.[31,34] We found no effects or associations of age on either adherence measure, but we did not evaluate the effect of OSA severity, gender, or comorbidities on adherence.

PAP usage of at least 70% for $>$ 4 h per night is considered adherent by many equipment providers and third-party payers.[22,23,32,35] However, total adherence provides information on the number of nights device use was at least attempted. Consequently, it is possible to utilize PAP on a nightly basis and be considered non-adherent if use is $<$ 4 h. A retrospective study that compared differences in adherence versus use in adults with OSA found that whereas 86% of subjects regularly used PAP adherence was only 63%.[35] Our findings were similar in that median adherence $>$ 4 h was lower than total adherence, both before and after PSG titration.

There were several limitations to our study. This was a retrospective chart review, and we did not collect information regarding the prescribed device brand or model, the type of mask interface, clinical status, actual h of use per night from the adherence report, or an explanation when adherence data were missing. There were only 4 subjects who did not attend a clinic visit prior to the follow-up PSG, and this was likely due to a short time frame between the initial and titration PSG. Several subjects were lost to follow-up after titration and did not attend further clinic appointments. Additional details surrounding the reasons for this were not within the scope of the study.

Although many follow-up appointments were attended, adherence data were not always reported. We speculate those who attended clinic visits but did not have adherence reported did not bring their equipment to the appointment. Those who attended, brought equipment, but had not used it were recorded as 0% adherence per the download report and were included in the analyses. Additionally, there is not a standard for device recorded data for the download from the home machine, and device model was not collected. Mask changes were also not evaluated, so it is unknown if this had an effect on adherence.

Another limitation is the age of the study period, and some of our practices have changed since that time. Currently, therapy changes are often based on the APAP adherence download prior to titration. Download reports are also now more easily accessible with remote access capabilities.

Despite the limitations, this study still provides relevant information regarding PAP management and adherence in children. The literature for pediatric use of APAP is limited. We were unable to identify any similar studies for outcomes of PSG titration following empirically prescribed PAP therapy in children. Although, a recent study of APAP in children found that pressures derived from the APAP device correlated with titration pressures,[19] whereas a previous comparison identified differences.[18]

PSG titration likely has a role in optimizing empirically prescribed PAP settings. Titration studies and therapy changes did not increase PAP adherence in the children we studied. Differences in adherence were not found for PAP settings or type of device in other studies.[23,24] Although PSG titration may assist with enhancing therapy, more research is necessary to determine the clinical implications of titration and therapy changes on adherence.

Conclusions

PSG titration studies frequently resulted in modifications to PAP therapy for the majority of children followed in our pediatric sleep disorders clinic. Titration studies may assist with optimization of PAP but do not seem to increase adherence. Changes in device type or settings adjustments did not have an impact on adherence. Further study is needed regarding the association of adherence and PSG titration.

REFERENCES

1. American Academy of Pediatrics. Clinical practice guideline: diagnosis and management of childhood obstructive sleep apnea. Pediatrics 2002;109(4):704-712.
2. Marcus CL, Brooks LJ, Draper KA, Gozal D, Halbower AC, Jones J, et al; American Academy of Pediatrics. Diagnosis and management of childhood obstructive sleep apnea syndrome. Pediatrics 2012;130(3): e714-755.
3. Tauman R, Gozal D. Obstructive sleep apnea syndrome in children. Expert Rev Respir Med 2011;5(3):425-440.
4. Aurora RN, Zak RS, Karippot A, Lamm CI, Morgenthaler TI, Auerbach SH, et al; American Academy of Sleep Medicine. Practice parameters for the respiratory indications for polysomnography in children. Sleep 2011;34(3):379-388.
5. Benedek P, Balakrishnan K, Cunningham MJ, Friedman NR, Goudy SL, Ishman SL, et al. International pediatric otolaryngology group (IPOG) consensus on the diagnosis and management of pediatric obstructive sleep apnea (OSA). Int J Pediatr Otorhinolaryngol 2020;138:110276.
6. Mitchell RB, Archer SM, Ishman SL, Rosenfeld RM, Coles S, Finestone SA, et al. Clinical practice guideline: tonsillectomy in

children (update). Otolaryngol Head Neck Surg 2019;160(1_suppl): S1-S42.
7. Patil SP, Ayappa IA, Caples SM, Kimoff RJ, Patel SR, Harrod CG. Treatment of adult obstructive sleep apnea with positive airway pressure: an American Academy of Sleep Medicine clinical practice guideline. J Clin Sleep Med 2019;15(2):335-343.
8. Littner M, Hirshkowitz M, Davila D, Anderson WM, Kushida CA, Woodson BT, et al; Standards of Practice Committee of the American Academy of Sleep Medicine. Practice Parameters for the Use of Auto-Titrating Continuous Positive Airway Pressure Devices for Titrating Pressures and Treating Adult Patients with Obstructive Sleep Apnea Syndrome. An American Academy of Sleep Medicine Report. Sleep 2002;25(2):143-147.
9. Hertegonne K, Bauters F. The value of auto-adjustable CPAP devices in pressure titration and treatment of patients with obstructive sleep apnea syndrome. Sleep Med Rev 2010;14(2):115-119.
10. Boudewyns A, Lanoir-Grillier V, Willemen MJ, De Cock WA, Van de Heyning PH, De Backer WA. Two months follow-up of auto-CPAP treatment in patients with obstructive sleep apnea. Thorax 1999;54(2):147-149.
11. Ayas NT, Patel SR, Malhotra A, Schulzer M, Malhotra M, Jung D, et al. Auto-titrating versus standard continuous positive airway pressure for the treatment of obstructive sleep apnea: results of a meta-analysis. Sleep 2004;27(2):249-253
12. Hukins C. Comparative study of auto-titrating and fixed-pressure CPAP in the home: a randomized single-blind crossover trial. Sleep 2004;27(8):1512-1517.
13. Fietze I, Glos M, Moebus I, Witt C, Penzel T, Baumann G. Automatic pressure titration with APAP is as effective as manual titration with CPAP in patients with obstructive sleep apnea. Respiration 2007;74 (3):279-286.
14. To KW, Chan WC, Choo KL, Lam WK, Wong KK, Hui DS. A randomized crossover study of auto-continuous positive airway pressure versus fixed-continuous positive airway pressure in patients with obstructive sleep apnea. Respirology 2008;13:76-86.
15. Bloch KE, Huber F, Furian M, Latshang TD, Lo Cascio CM, Nussbaumer-Ochsner Y, et al. Auto-adjusted versus fixed CPAP for obstructive sleep apnea: a multi-center, randomized equivalence trial. Thorax 2018;73(2):174-184.
16. 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):e412-e417.
17. Marshall MJ, Bucks RS, Hogan AM, Hambleton IR, Height SE, Dick MC, et al. Auto-adjusting positive airway pressure in children with sickle cell anemia: results of a phase 1 randomized controlled trial. Haematologica 2009;94(7):1006-1010.
18. Mihai R, Vandeleur M, Pecoraro S, Davey MJ, Nixon GM. Auto-titrating CPAP as a tool for CPAP initiation for children. J Clin Sleep Med 2017;13(05):713-719.
19. Khaytin I, Tapia IE, Xanthopoulos MS, Cielo CC, Kim JY, Smith J, et al. Auto-titrating CPAP for the treatment of obstructive sleep apnea in children. J Clin Sleep Med 2020;16(6):871-878.
20. Sangal RB. Auto-titrating CPAP for the treatment of obstructive sleep apnea in children: APAP and CPAP pressures were not that close. J Clin Sleep Med 2020;16(10):1823-1823.
21. Khaytin I, Tapia IE, Beck SE. Auto-titrating CPAP for the treatment of obstructive sleep apnea in children: a good beginning. J Clin Sleep Med 2020;16(10):1825-1826.
22. Jambhekar SK, Com G, Tang X, Pruss KK, Jackson R, Bower C, et al. Role of a respiratory therapist in improving adherence to positive airway pressure treatment in a pediatric sleep clinic. Respir Care 2013;58 (12):2038-2044.
23. Hawkins SMM, Jensen EL, Simon SL, Friedman NR. Correlates of pediatric CPAP adherence. J Clin Sleep Med 2016;12(6):879-884.
24. Sawyer AM, Gooneratne N, Marcus CL, Ofer D, Richards KC, Weaver TC. A systematic review of CPAP adherence across age groups: clinical and empiric insights for developing CPAP adherence interventions. Sleep Med Rev 2011;15(6):343-356.
25. Aloia MS. Understanding the problem of poor CPAP adherence. Sleep Med Rev 2011;15(6):341-342.
26. Drummond F, Doelken P, Ahmed QA, Gilbert GE, Strange C, Herpel L, Frye MD. Empiric auto-titrating CPAP in people with suspected obstructive sleep apnea. J Clin Sleep Med 2010;06(02):140-145.
27. Iber C, Ancoli-Israel S, Chesson AL. The AASM manual for the scoring of sleep and associated events: rules, terminology, and technical specifications, 1st edition. Westchester, Illinois: American Academy of Sleep Medicine; 2007.
28. Vennelle M, White S, Riha RL, Mackay TW, Engleman HM, Douglas NJ, et al. Randomized controlled trial of variable-pressure versus fixed-pressure continuous positive airway pressure (CPAP) treatment for patients with obstructive sleep apnea/hypopnea syndrome (OSAHS). Sleep 2010;33(2):267-271.
29. Widger JA, Davey MJ, Nixon GM. Sleep studies in children on long-term noninvasive respiratory support. Sleep Breath 2014;18(4):885-889.
30. Al-Saleh S, Sayal P, Stephens D, Florence J, Sayal A, Baker A, et al. Factors associated with changes in invasive and noninvasive positive airway Pressure Therapy settings during pediatric polysomnograms. J Clin Sleep Med 2017;13(2):183-188.
31. Parmar A, Messiha S, Baker A, Zweerink A, Toulany A, Narang I. Caregiver support and positive airway pressure therapy adherence among adolescents with obstructive sleep apnea. Paediatr Child Health 2020;25(8):491-497.
32. Blinder H, Momoli F, Holland SH, Blinder A, Radhakrishnan D, Katz SL. Clinical predictors of nonadherence to positive airway pressure therapy in children: a retrospective cohort study. J Clin Sleep Med 2021;17(6):1183-1192.
33. Cielo CM, Hernandez P, Ciampaglia AM, Xanthopoulos MS, Beck SE, Tapia IE. Positive airway pressure for the treatment of OSA in infants. Chest 2021;159(2):810-817.
34. DiFeo N, Meltzer LJ, Beck SE, Karamessinis LR, Cornaglia MA, Traylor J, et al. Predictors of positive airway pressure therapy adherence in children: a prospective study. J Clin Sleep Med 2012;8(3):279-286.
35. Krakow B, Ulibarri VA, Foley-Shea MR, Tidler A, McIver ND. Adherence and subthreshold adherence in sleep apnea subjects receiving positive airway pressure therapy: a retrospective study evaluating difference in adherence versus use. Respir Care 2016;61(8):1023-1032.