

Can Auto-CPAP Determine Therapeutic CPAP Pressure in Children with OSA?

Rapee Opasatian, Aroonwan Preutthipan*

Division of Pediatric Pulmonology, Department of Pediatrics, and Sleep Disorder Center, Faculty of Medicine, Ramathibodi Hospital, Bangkok, Thailand

Abstract

Objective: In current standard practice the therapeutic pressure of CPAP is determined by manually titration under attended polysomnography (PSG). Since PSG is not easily accessible, auto-CPAP may be an attractive alternative. Our goal is to compare the pressure levels obtained from home auto-CPAP with overnight PSG titration in children with OSA.

Methods: We performed a prospective cohort study in 2-18 year-old children with OSA referred for CPAP titration under PSG. Children were instructed to use auto-CPAP devices at home for 8 weeks, either before or after PSG titration. One night PSG titration was performed following AASM clinical guidelines for the manual titration of positive airway pressure. Data from only those children who used auto-CPAP ≥ 4 hours per day, for $>$ consecutive 7 days and percent days with device usage $\geq 80\%$ were selected for analysis. Average device pressure $\leq 90\%$ of time from auto-CPAP were obtained and compared with PSG titrating pressure.

Results: Eleven of 17 children were enrolled and completed the protocol (male 9/11, aged 9.6 ± 4.2 years, BMI 31.5 ± 10.0 kg/m²). Three children refused to use auto-CPAP. Three children were non-adherence. Six of 11 children had already undergone adenotonsillectomy. There were no significant differences in the pressure levels obtained from home auto-CPAP and PSG titration (11.05 ± 3.68 vs. 11.18 ± 3.34 cm H₂O, $p=0.84$). However, when considering on actual values of the pressure, only 5/11 children had pressure differences <2 cm H₂O. Pressure levels obtained from auto-CPAP significantly differed from PSG titration in the group of children with history of adenotonsillectomy ($p=0.036$).

Conclusion: In children with OSA, the use of home auto-CPAP may not accurately determine the therapeutic CPAP pressure as compared with manually titration under attended PSG, especially in children who previously had adenotonsillectomy.

Keywords: Auto-titrating positive airway pressure; Positive airway pressure therapy; Obstructive sleep apnea; Children; Adenotonsillar hypertrophy; Polysomnography; Adenotonsillectomy.

Introduction

In adults, the treatment of choice for obstructive sleep apnea (OSA) is continuous positive airway pressure (CPAP) device, which functions by blowing air into the airway to overcome the critical closing pressure of the pharynx and maintain a patent pharyngeal airway during sleep [1]. Unlike adults, CPAP is considered in children only when OSA persists despite adenotonsillectomy or such surgery is contraindicated. The pressure level that each patient requires needs to be titrated individually under attended polysomnography, during which CPAP pressure is started at a low level and progressively increased to find the level at which the following obstructive respiratory events, including apneas, hypopneas, respiratory effort-related arousals, and snoring, are eliminated. The pressure required for resolution of events is often higher if the patient is supine, and may be higher in REM sleep when muscle tone is the lowest. Therefore, the final prescription should reflect the single fixed pressure required to treat the worst apnea in supine REM sleep [2]. To standardize CPAP titration technique, the American Academy of Sleep Medicine (AASM) have published a clinical guideline for the manual titration of CPAP pressure in OSA patients in 2008 [3].

Over the last two decades, auto-CPAP machines have developed and focused mainly for adult patients. The CPAP pressure was initially set up as a range: Lowest and highest pressure levels. The machines are programmed to adjust CPAP pressure automatically based on detection of apnea, hypopnea, flow limitation, snoring, pressure fluctuations or increased airway resistance. With the implement of auto-CPAP, the need for CPAP titration under polysomnography is supposedly

decreased. A systematic review with meta-analyses on 24 randomized controlled trials comparing auto-CPAP with single fixed pressure CPAP in adults with OSA found that auto-CPAP improved compliance by 11 minutes per night and reduced the Epworth Sleepiness Scale by 0.5 points. Although statistically significant differences were found but clinical importance was unclear. Therefore the choice of therapy still depends on patient's preference or cost [4].

There have been relatively fewer studies of auto-CPAP use in children as compared to adults. In 2004, Polombini et al. demonstrated that auto-CPAP was safe and effective for children with OSA in an attended setting. It was also found to be useful for pressure titration [5]. In 2009, Marshall et al. demonstrated that auto-CPAP was feasible and safe to be used at home in children with sickle cell anemia, which resulted in improved sleep-related breathing disorders and at least one aspect of cognition [6].

All auto-CPAP devices have a slot in the machine allowing for a smart card to capture data. The data can be downloaded and viewed

*Corresponding author: Preutthipan A, Division of Pediatric Pulmonology, Department of Pediatrics, and Sleep Disorder Center, Faculty of Medicine, Ramathibodi Hospital, Bangkok, Thailand, Tel: 6622011727; Email: aronwan.pre@mahidol.ac.th

Received March 24, 2018; Accepted September 04, 2018; Published JSeptember 20, 2018

Citation: Opasatian R, Preutthipan A (2018) Can Auto-CPAP Determine Therapeutic CPAP Pressure in Children with OSA?. J Sleep Disord Ther 7: 295 doi: [10.4172/2167-0277.1000295](https://doi.org/10.4172/2167-0277.1000295)

Copyright: © 2018 Opasatian R, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

or printed out. Some machines report not only the patients' adherence but also the amount pressure the patients have received and express as an average pressure and as a percentile pressure. In 2017, Mihai et al. conducted a retrospective study in children comparing these downloaded pressure data with the CPAP pressure determined by PSG. They found that downloaded pressure from auto-CPAP report were usually below treatment pressure determined under PSG [7]. Since this study was a retrospective review and recruited CPAP-naïve children whose parents reported CPAP use of at least 1 to 2 hours a night, 39% of the children were found to be non-adherence as using auto-CPAP less than 90% of the time. Therefore downloaded pressure data may be confounded with the data from non-adherence children. We hypothesized that if the children were adherence to auto-CPAP, downloaded pressure data might be closed to the CPAP pressure determined by attended PSG titration. If so, instead of performing PSG titration, auto-CPAP could be started in a new patient right after diagnosis of OSA and the optimum CPAP pressure level could be obtained easily from downloaded data. For any cost reasons, the patient could transition to fixed pressure CPAP afterwards. So the objective of this prospective study was to compare the pressure level derived from auto-CPAP downloaded data with the CPAP pressure determined under attended PSG in children with OSA.

Materials and Methods

Subjects

The study was conducted prospectively from February 2016 to January 2017. We enrolled children aged 2 to 18 years old, diagnosed with OSA by PSG. They needed CPAP therapy and were willing to use auto-CPAP at home with acceptance from parents. Children with neuromuscular weakness and central hypoventilation were excluded. This study was approved by the Institutional Review Board (IRB) of Ramathibodi Hospital. All children and parents provided informed consent.

Methods

Polysomnographic studies

A standard attended PSG for titration of CPAP, was performed at Ramathibodi Hospital Sleep Disorder Center. We used PSG equipment (Graef system, Compumedics, Melbourne, Australia). The measured parameters included the recording of frontal, central and occipital electroencephalograms, left and right electrooculograms, submental and bilateral tibial electromyogram, electrocardiogram, nasal thermistor, nasal pressure, pulse oximetry, end tidal CO₂, thoracic and abdominal belt for respiratory effort monitoring, and infra-red camera. Signals were recorded with Compumedics® (Compumedics Ltd, Abbotsford, Australia) and scored following the American Academy of Sleep Medicine (AASM) criteria [8]. Apneas were defined as a drop in peak signal excursion by $\geq 90\%$ of pre-event baseline using oronasal thermal sensor. Obstructive apnea defined by criteria of apnea for at least duration of 2 breaths during baseline breathing and associated with presence of respiratory effort. Hypopneas were defined as a peak signal excursions drop by $\geq 30\%$ of pre-event baseline using nasal pressure and the duration lasts for ≥ 2 breaths and $\geq 3\%$ oxygen desaturation from pre-event baseline of the event associated with arousal. Children were accompanied by parents throughout the night. The studies were conducted by two skillful clinical sleep technicians experienced with children. One night PSG titration was performed following AASM clinical guidelines for the manual titration of positive airway pressure [3], with the goal to eliminate all obstructive apneas and hypopneas and minimize arousals and snoring.

Auto-CPAP studies

All patients were instructed to use auto-CPAP devices (System One REMstar Auto, Philips Respironics Inc, Murrysville, Pennsylvania, United States). This device detects upper airway resistance by flow limitation. It measures changes in airflow by an internal pneumotachograph to identify respiratory events. If flow decreases by 40% to 80% for at least 10 sec, the event is labeled a hypopnea; a decrease in flow by more than 80% for at least 10 sec is labeled an apnea [9,10]. The device starts off at the minimum pressure set point for five minutes. At this minimum pressure setting, the patient is awake and the upper airway is patent and upper airway resistance is low. As the patient falls asleep the upper airway begins to collapse thus increasing the resistance. The device then delivers proper pressure until there is no flow limitation [11].

Auto-CPAP was assigned to be used at home for 2 weeks either before or after PSG titration. The period in between the use of auto-CPAP at home and PSG titration was less than 8 weeks. The study flow diagram is shown in Figure 1. Auto-CPAP pressure were adjusted to 4-15 cm H₂O in children aged <12 years, and 4-20 cm H₂O in children aged >12 years. Mask fitting was completed by our clinical sleep technicians. We let the patients select their own masks according to their preference to optimize acceptability and comfort. Another important aim of mask fitting was to minimize leaks. The patient came back to our sleep clinic after two weeks of home auto-CPAP. The data from auto-CPAP were downloaded using EncorePro Basic (Philips Respironics Inc, Murrysville, Pennsylvania, United States). The pressure parameter taken from the standard report was "average device pressure $\leq 90\%$ of time", at which the device spent 90% of the session time at or below this pressure. Adherence data were also downloaded. Data from only those who used auto-CPAP ≥ 4 hours per day, for >consecutive 7 days and percent days with device usage $\geq 80\%$ were selected for analysis. Average device pressure $\leq 90\%$ of time from auto-CPAP was compared with PSG titrating pressure.

Statistical analysis

Data were analyzed using SPSS version 20. Descriptive statistics include mean, standard deviation, and median values. The data are expressed as the mean+SD for continuous variables or numbers and percentages for categorical variables. Continuous variables were compared using paired Student t test or the Mann-Whitney test. Categorical variables were compared using the χ^2 test or the Fisher's exact test. Relationship between two continuous variables was assessed using Pearson's correlation coefficient. A p value of <0.05 was considered statistically significant.

Results

Seventeen OSA patients who needed CPAP therapy were invited

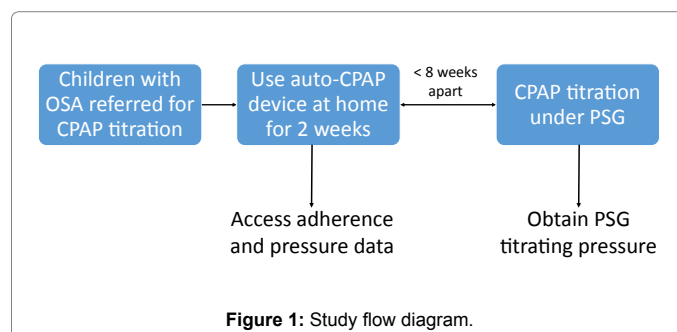


Figure 1: Study flow diagram.

to participate to the study. Three patients refused to use auto-CPAP at home. Another three patients who failed to meet the criteria of CPAP adherence were excluded. Informed consent was obtained from all individual participant included in the study. Data from 11 patients were analyzed in this study. Of the remaining 11 patients, 9 (82%) were male. Demographic data are shown in Table 1. Six (55%) were obese. Mean body mass index z-score was above 2.0. Five (45%) presented with enuresis. Nine (82%) had severe OSA as apnea hypopnea index >10 events/h. All of our patients had been treated with intranasal corticosteroids and leukotriene inhibitor. Six (55%) had undergone adenotonsillectomy.

Average device pressure \leq 90% of time derived from auto-CPAP was 11.05+3.68 cmH₂O, and PSG titrating pressure was 11.18+3.34 cm H₂O. There was no statistically significant difference between these two pressure variables (p value=0.84). However, when considering on actual values of the pressure as shown in Figure 2, 6 (55%) patients had pressure differences >2 cm H₂O as shown in Figure 3, 3 (27%) had pressure differences >4 cm H₂O. PSG pressure was higher than auto-CPAP pressure in 5 patients and lower in 6 patients. The largest difference was 9.3 cm H₂O found in the last patient as shown in Figure 3.

Of 6 patients with history of adenotonsillectomy, 5 (83%) had pressure differences >2 cmH₂O. In contrast to 5 patients without history of adenotonsillectomy, there was only 1 (20%) patient having pressure differences >2 cmH₂O. Fisher's exact test showed a statistically significant difference between these two percentages (p value=0.036).

No other conditions of the patients (including age, sex, body mass index, OSA severity, allergic rhinitis, Prader Willi Syndrome) were found to be associated with the pressure differences >2 cm H₂O.

Figure 4a shows no correlation between PSG pressure and auto-CPAP pressure in patients with history of adenotonsillectomy (r=0.03, p value=0.518) in contrast to the patients without history of adenotonsillectomy, in whom PSG pressure correlates well with auto-CPAP pressure (r=0.91, p value=0.035) as shown in Figure 4b.

No patients reported adverse events from auto-CPAP.

Discussion

This pilot study indicates that although auto-CPAP devices are safe to be used in children, they cannot be used to determine the optimal CPAP pressure requirement or replace CPAP titration under PSG. The actual pressure levels derived from auto-CPAP differed from PSG pressure greater than 2 cmH₂O in more than half of the patients. Auto-CPAP pressure levels were found to be either higher or lower than PSG pressure. And the pressure difference was as high as 9 cm H₂O in one patient. The findings of this study suggest that a manual CPAP titration under attended PSG is still essential to determine the most effective pressure for fixed-pressure CPAP in children.

Most of the studies with similar objectives comparing the pressure levels derived from auto-CPAP with PSG titrating pressure have been conducted in adults. The results were not consistent. Luo et al. found that automatic titration pressure derived from REM star Auto was

Demographic data		
Sex (male), n		9
Age (mean \pm SD, range), year		9.6 \pm 4.2, 4-17
Body weight (range), Kg		12.6-122
BMI (mean \pm SD, range), Kg/m ²		31.5 \pm 10.0, 14.9-45.9
BMI Z-score (mean \pm SD)		3.8 \pm 2.4
Weight for height (mean \pm SD), %		184.5 \pm 62.1
Clinical manifestation		
Snoring		100%
Abnormal breathing during sleep		64%
Enuresis		45%
Excessive daytime sleepiness		27%
Underlying diseases		
Adenotonsillar hypertrophy		73%
Allergic rhinitis		45%
Obesity (%W/H>140)		55%
Morbid obesity (%W/H>200)		27%
Prader-Willi syndrome		18%
OSA severity		
AHI range		5.7-135.7
Moderate OSA (AHI 5-10)		18%
Severe OSA (AHI>10)		82%
Previous OSA treatment		
Intranasal corticosteroids		100%
Leukotriene inhibitor		100%
Adenotonsillectomy		54.50%
Auto-CPAP pressure (mean \pm SD), cmH ₂ O		11.05 \pm 3.68
Attended PSG pressure (mean \pm SD), cmH ₂ O		11.18 \pm 3.34
*Comparison between auto-CPAP pressure and attended PSG pressure		
BMI: body mass index, W/H: weight for height, OSA: obstructive sleep apnea, AHI: apnea- hypopnea index, CPAP: continuous positive airway pressure, PSG: polysomnography		

Table 1: Demographic data of participants (n = 11).

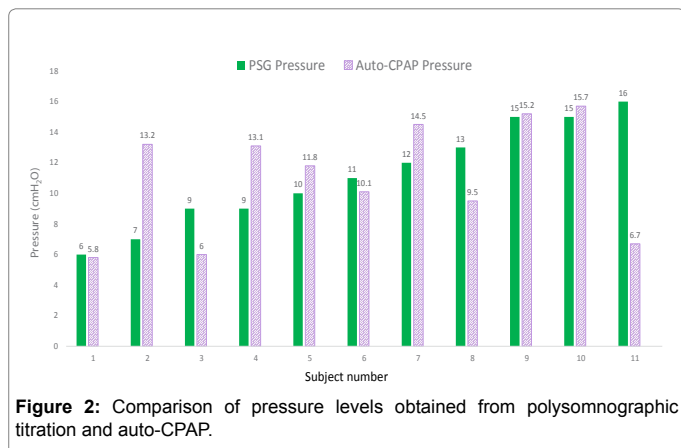


Figure 2: Comparison of pressure levels obtained from polysomnographic titration and auto-CPAP.

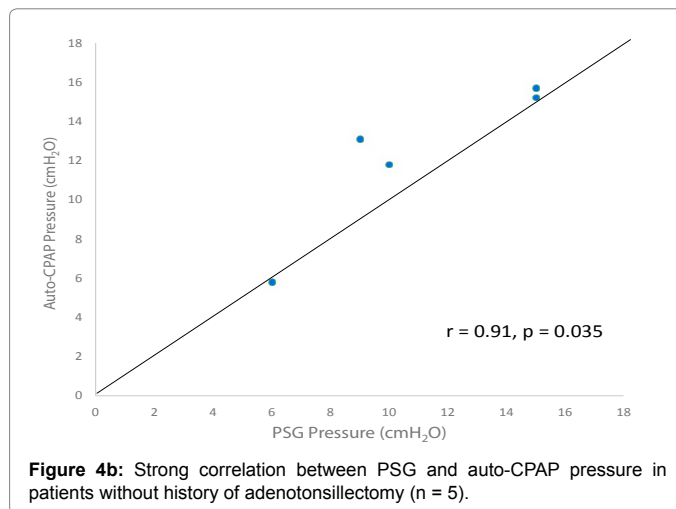


Figure 4b: Strong correlation between PSG and auto-CPAP pressure in patients without history of adenotonsillectomy (n = 5).

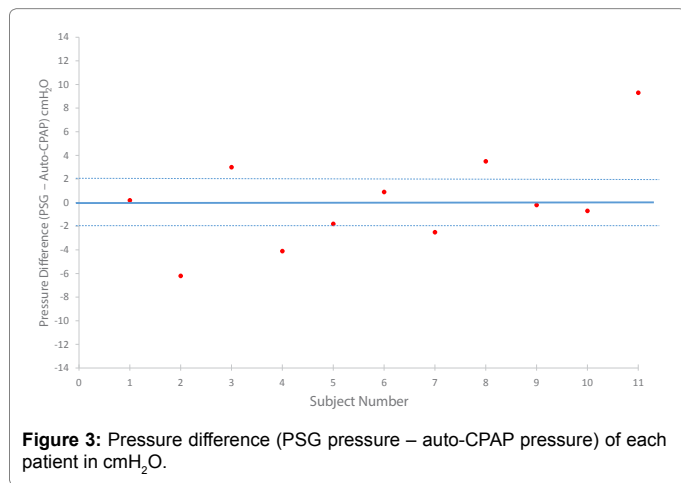


Figure 3: Pressure difference (PSG pressure – auto-CPAP pressure) of each patient in cmH₂O.

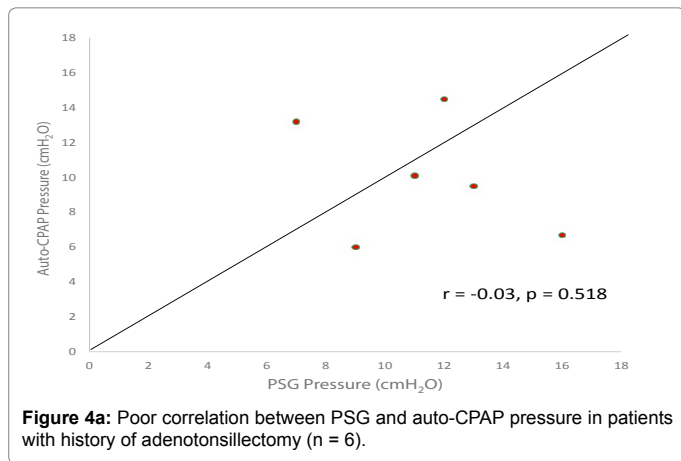


Figure 4a: Poor correlation between PSG and auto-CPAP pressure in patients with history of adenotonsillectomy (n = 6).

significantly higher than that derived from manual titration under PSG [12]. Choi et al. reported no significant differences in pressure level between full-night manual titration and auto-adjusting titration [13]. Lloberes et al. found that daytime auto-CPAP titration yielded a higher treatment pressure than PSG titration but the clinical outcomes were similar [14].

So far very few studies on auto-CPAP have been conducted in children. Mihai et al. conducted a retrospective study comparing treatment pressure derived from auto-CPAP and those from overnight PSG titration. They found that average device pressure < 90% of time

downloaded from auto-CPAP did not statistically differ from PSG pressure. However the pressure difference falling within 2 cm H₂O were noted only in 69% of cases. The magnitude of difference ranged from 8 cm H₂O under PSG pressure to 3 cm H₂O over PSG pressure [7]. The results of Mihai’s study were compatible with our current study. In addition to the results and recruiting children as subjects, the similarity between ours and Mihai’s study was the use of REMstar Auto as a single auto-CPAP device at home, not in the sleep laboratory. We also selected average device pressure <90% of time as a representative of auto-CPAP pressure. Dissimilar factors that strengthened of our study were the prospective study design and non-adherence subjects were excluded. We selected patients only those who used auto-CPAP ≥ 4 hours per day, for >consecutive 7 days and percent days with device usage ≥ 80% in comparison with Mihai’s study that included patients who used at least 1 to 2 hours a night. One limitation of our study was a smaller sample size that may explain why the differences in pressure levels derived from the two techniques could not be demonstrated.

Our study confirmed that auto-CPAP devices were well tolerated and safe to be applied in children with no adverse effects reported. Only 3 out of 14 recruited children failed to meet the criteria of CPAP adherence. The youngest age of our adherence patients was found to be 4 years with the body weight of 12.6 Kg. This indirect evidence confirmed the usefulness of auto-CPAP in children with OSA as reported by Palombini et al, Marshall et al. and Mihai et al. Unfortunately we did not collect data of the polysomnographic parameters, oxygen saturation or the quality of life that might be improved after auto-CPAP therapy [5-7].

One interesting finding was the effect of adenotonsillectomy to the pressure difference. In children with no history of adenotonsillectomy the pressure determined by auto-CPAP correlated well with PSG titration pressure. However, in children who had undergone adenotonsillectomy there was no significant correlation. The effect of adenotonsillectomy on the function of auto-CPAP devices have never been described before. In adults, upper airway surgical treatment was found to have some benefits by reducing nasal CPAP pressure levels [15,16]. In children, adenotonsillectomy also reduces CPAP requirement most likely due to alleviation of upper airway obstruction [17]. However it is unknown why auto-CPAP devices function differently in patients with and without history of adenotonsillectomy. It is likely that there may be some changes in the pattern of air flow through the upper airway surrounded by surgical scar resulting in the changing pattern of auto-CPAP response. Further studies on this issue are needed to confirm and

explain this finding.

It should be noted that we used the same auto-CPAP device in all children. Our results cannot be applied to other brands of auto-CPAP since different devices used different proprietary algorithms to adjust pressure and the performance of one device should not be assumed to be equivalent to that of another [18]. Isetta et al. conducted a bench test to assess how 7 available auto-CPAP devices respond to a simulated OSA patient. They found wide variations in mean and maximum pressure, and also the time to reach maximum pressure [19]. Therefore the pressure derived from each brand of auto-CPAP may not be the same.

In conclusion, although auto-CPAP is safe to be used at home in children, it cannot replace the role of PSG titration in determining the most effective fixed pressure level of long-term CPAP therapy in children with OSA.

Limitation

Although the number of subjects is only 11, we still see the difference of pressure levels greater than 2 cm H₂O in more than half of the patients. We use 2 cm H₂O as a cutoff of pressure difference because this is important in clinical practice. The magnitude of pressure difference in one patient is as high as 9 cm H₂O which may cause harmful effect clinically. Therefore the pressure level obtained from auto-CPAP cannot be used to replace the pressure derived from polysomnography. Auto-CPAP pressure levels were either higher or lower than PSG pressure. So it would be too difficult to predict optimal pressure from auto-CPAP.

Acknowledgements

We thank Teeradej Kuptanon, Wanaporn Anantaseree, Pravit Jetanachai, Anchalee Leejakpai, Vijitra Hongtong and Ramathibodi Hospital Sleep Disorder Center for all their support. Moreover, our special thanks go to children and parents who kindly participated in this project.

Conflict of interest

The authors declare that they have no conflict of interest.

Funding

No funding was received for this research.

References

- Huang J, Pinto SJ, Yuan H, Katz ES, Karamessinis LR, et al. (2012) Upper airway collapsibility and genioglossus activity in adolescents during sleep. *Sleep* 35: 1345-1352.
- Halbower A (2018) CPAP for pediatric obstructive sleep apnea. In: Chervin R, Hoppin A, editors. *UpToDate*. UpToDate, Waltham, MA.
- Kushida CA, Chediak A, Berry RB, Brown LK, Gozal D, et al. (2008) Clinical guidelines for the manual titration of positive airway pressure in patients with obstructive sleep apnea. *J Clin Sleep Med* 4: 157-171.
- Ip S, D'Ambrosio C, Patel K, Obadan N, Kitsios GD, et al. (2012) Auto-titrating versus fixed continuous positive airway pressure for the treatment of obstructive sleep apnea: A systematic review with meta-analyses. *Syst Rev* 1: 20.
- Palombini L, Pelayo R, Guilleminault C (2004) Efficacy of automated continuous positive airway pressure in children with sleep-related breathing disorders in an attended setting. *Pediatrics* 113: e412-e417.
- Marshall MJ, Bucks RS, Hogan AM, Hambleton IR, Height SE, et al. (2009) Auto-adjusting positive airway pressure in children with sickle cell anemia: Results of a phase I randomized controlled trial. *Haematologica* 94: 1006-1010.
- Mihai R, Vandeleur M, Pecoraro S, Davey M, Nixon G (2017) Autotitrating CPAP as a tool for CPAP initiation for Children. *J Clin Sleep Med* 13: 713.
- Berry RB, Budhiraja R, Gottlieb DJ, Gozal D, Iber C, et al. (2012) Rules for scoring respiratory events in sleep: Update of the 2007 AASM manual for the scoring of sleep and associated events. deliberations of the sleep apnea definitions task force of the american academy of sleep medicine. *J Clin Sleep Med* 8: 597-619.
- Gagnadoux F, Pevernagie D, Jennum P, Lon N, Loiodice C, et al. (2017) Validation of the system one remstar auto A-flex for obstructive sleep apnea treatment and detection of residual apnea-hypopnea index: A european randomized trial. *J Clin Sleep Med* 13: 283-290.
- Li QY, Berry RB, Goetting MG, Staley B, Soto-Calderon H, et al. (2015) Detection of upper airway status and respiratory events by a current generation positive airway pressure device. *Sleep* 38: 597-605.
- Morgenthaler TI, Aurora RN, Brown T, Zak R, Alessi C, et al. (2008) Practice parameters for the use of autotitrating continuous positive airway pressure devices for titrating pressures and treating adult patients with obstructive sleep apnea syndrome: An update for 2007. *Sleep* 31: 141-147.
- Luo J, Xiao S, Qiu Z, Song N, Luo Y (2013) Comparison of manual versus automatic continuous positive airway pressure titration and the development of a predictive equation for therapeutic continuous positive airway pressure in chinese patients with obstructive sleep apnoea. *Respirology* 18: 528-533.
- Choi JH, Jun YJ, Oh JI, Jung JY, Hwang GH, et al. (2013) Optimal level of continuous positive airway pressure: Auto-adjusting titration versus titration with a predictive equation. *Ann Otol Rhinol Laryngol* 122: 339-343.
- Lloberes P, Rodriguez B, Roca A, Sagales MT, de la Calzada MD, et al. (2004) Comparison of conventional nighttime with automatic or manual daytime CPAP titration in unselected sleep apnea patients: Study of the usefulness of daytime titration studies. *Respir Med* 98: 619-625.
- Zonato AI, Bittencourt LRA, Martinho FL, Gregório LC, Tufik S (2006) Upper airway surgery: The effect on nasal continuous positive airway pressure titration on obstructive sleep apnea patients. *Eur Arch Otorhinolaryngol* 263: 481-486.
- Ayers CM, Lohia S, Nguyen SA, Gillespie MB (2016) The effect of upper airway surgery on continuous positive airway pressure levels and adherence: A systematic review and meta-analysis. *ORL J Otorhinolaryngol Relat Spec* 78: 119-25.
- Shine NP, Lannigan FJ, Coates HL, Wilson A (2006) Adenotonsillectomy for obstructive sleep apnea in obese children: Effects on respiratory parameters and clinical outcome. *Arch Otorhinolaryngol* 132: 1123-1127.
- Zhu K, Roisman G, Aouf S, Escourrou P (2015) All APAPs are not equivalent for the treatment of Sleep Disordered Breathing: A bench evaluation of eleven commercially available devices. *J Clin Sleep Med* 11: 725-734.
- Isetta V, Navajas D, Montserrat JM, Farre R (2015) Comparative assessment of several automatic CPAP devices' responses: A bench test study. *ERJ Open Res* 1: 00031.