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Clinical Feasibility of an Auto-Adjusting Bi-Level PAP Device for the Treatment of Obstructive Sleep Apnea

Obtrüktif Uyku Apne Tedavisinde Otomatik BPAP Cihazının Klinik Yararlılığı

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Summary

Introduction: Bi-Level positive airway pressure (BPAP) is an effective alternative to continuous positive airway pressure (CPAP) in patients with obstructive sleep apnea (OSA) who could not tolerate CPAP. An automatically titrating BPAP device has recently been developed, BPAP Auto® with BiFlex™ (BPAPauto). The primary aim of this study was to examine the performance of this new device during attended polysomnography (PSG).

Materials and Methods: This was a prospective case series study. Participants with OSA currently using CPAP or BPAP therapy were recruited and undergo in-lab PSG study with BPAPauto.

Results: A total of 27 participants met the criteria, enrolled the study. All participants received BPAPauto therapy during an attended PSG. Sleep and respiratory data were examined. The mean apnea hypopnea index was found 2.2±2.5 events/hour. SaO_2 (oxygen saturation) was 94.0%±1.8. The mean inspiratory positive airway pressure (IPAP) abolish respiratory events was 14.1±3.4 cmH_2O and that of expiratory positive airway pressure (EPAP) was 10.7±3.9 cmH_2O.

Conclusions: BPAPauto is able to establish an appropriate Bi-Level PAP and control oxygen saturation without excessive disruption of sleep. Further studies using randomized control design are needed to examine potential roles and advantages of BPAPauto for treatment of OSA. (*JTSM 2014;3:66-70)*

Key Words: obstructive sleep apnea, bi-level continuous positive airway pressure, continuous positive airway pressure

Özet

Giriş: CPAP'ı tolere edemeyen tıkayıcı uyku apne hastalarında BPAP, CPAP'ın etkin bir alternatifidir. BPAP Auto® with BiFlex™ (BPAPauto) cihazı son zamanlarda geliştirilen bir otomatik titrasyon özelliği olan BPAP'dır. Bu çalışmanın amacı bu yeni cihazın etkinliğini laboratuvar ortamında yapılan polisomnografi (PSG) ile değerlendirmektir.

Gereç ve Yöntem: Bu çalışma prospektif vaka-kontrol çalışmasıdır. Hale hazırda BPAP veya CPAP cihazı kullanan obstrüktif uyku apneli hastalar çalışmaya alındı ve BPAPauto cihazı ile laboratuar ortamında PSG yapıldı.

Bulgular: Çalışma kriterlerini karşılayan 27 hasta çalışmaya alındı. Tüm çalışmaya alınan hastalara laboratuvar ortamında yapılan PSG eşliğinde BPAPauto tedavisi verildi. Uyku ve solunum parametreleri incelendi. Ortalama apne-hipoapne indeksi 2,2±2,5 olay/saat olarak bulundu. SaO_2 (oksijen saturasyonu) %94,0±1,8 bulundu. Solunum olaylarının düzeltmek için gereken ortalama inspiratuvar pozitif hava yolu basıncı (IPAP) 14,1±3,4 cmH_2O ve ortalama ekspiratuvar pozitif hava yolu basıncı (EPAP) 10,7±3,9 cmH_2O bulundu.

Sonuç: BPAPauto uyku kalitesini bozmaksızın, uygun BPAP basınçlarını ayarlayabilmekte ve oksijen saturasyonunu kontrol altında tutabilmektedir. Obstrüktif uyku apnenin tedavisinde BPAPauto'nun avantajlarının ve potansiyel rollerinin incelene bilmesi için daha ileri randomize kontrollü çalışmalara ihtiyaç vardır. (*JTSM 2014;3:66-70)*

Anahtar Kelimeler: Obstrüktif uyku apne, BPAP, CPAP

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Introduction

Obstructive sleep apnea syndrome is a common clinical problem effecting approximately 2-4% of the adult population (1). It is characterized by intermittent and recurrent upper airway occlusion during sleep (2). The resulting airway narrowing and/or closure restrict airflow and can produce repeated oxyhemoglobin desaturations, sleep fragmentation, or both. Continuous positive airway pressure (CPAP) is a standard treatment for patients with OSA (3,4). Positive airway pressure (PAP) is a very effective treatment but only if it is used on a regular basis (5). A comprehensive review of CPAP literature found non-acceptance rates to vary from 5 to 50%, with the average of approximately 20%. Another 12 to 15% can be expected to stop PAP treatment within 3 years. Of those using PAP, adherence rates (>4 h use for 70% of days) have varied from 40 to 80% (6,7). A major challenge facing clinicians is improving adherence to PAP treatment (8). While the literature mainly supports CPAP therapy, Bi-level PAP (BPAP) is an optional therapy in some cases where high pressure is needed and the patient experiences difficulty exhaling against a fixed pressure (4,9,10). BPAP delivers a separately adjustable lower expiratory positive airway pressure (EPAP) and higher inspiratory positive airway pressure (IPAP) (9,11).

BiPAP with Bi-Flex offers a unique form of bi-level therapy by which Bi-Flex provides flow-directed modification to the transition into and out of the IPAP phase, and dynamic expiratory pressure relief. The amount of expiratory pressure relief is determined by the patient's expiratory flow. Accordingly, the pressure returns to therapeutic levels prior to the initiation of the next breath's inspiratory phase. The pressure relief offers a more comfortable expiratory experience for the patient, and may impact favorably on perceptions of therapy as well as potentially long-term acceptance to therapy (5).

The primary aim of this study was to examine the performance of BiPAP Auto® with BiFlex™ (BPAPauto; respironics corporation) device during attended polysomnography (PSG) for the treatment of OSA. Specifically; (1) to automatically adjust EPAP and IPAP pressure to maintain a therapeutic apnea-hypopnea index (AHI), (2) to automatically adjust EPAP and IPAP pressure to maintain airway potency, (3) to maintain low average treatment pressure, and (4) to maintain acceptable sleep architecture.

Materials and Methods

Participants

Subjects with OSA currently using CPAP or BPAP therapy were recruited from the University of Pittsburgh Medical Center (UPMC), Sleep Medicine Center where they have been diagnosed with OSA and are currently being treated with fixed PAP. Patients who met all criteria for participation and provided informed consent were scheduled to undergo in-lab PSG study with BPAPauto with BiFlex. Participants were also asked to bring their own mask and accessories in order to maximize their comfort. Inclusion criteria of the study were; 1. Fixed CPAP users with a prescription ≥8 cmH_2O or fixed BPAP users with any Bi-Level prescription, 2. The Sleep disordered breathing events were required to be primarily obstructive in nature (>50%), 3. Age ≥18 years, 4. No weight change in excess of ± 15 pounds since last titration (<1 year), 5. Able to follow instructions, 6. Able to provide inform consent. Exclusion criteria were; 1. CPAP prescription of <8 cmH_2O , 2. An artificial airway, 3. Current acute upper respiratory infection, encephalitis, sinusitis or middle ear infection, 4. Acute dermatitis or other skin lesions or trauma interfering with the application of a mask, 5. Co-morbid conditions including cardiopulmonary diseases, COPD, heart failure or receiving anticoagulants. The study was approved by Western Institutional Review Board (WIRB) and UPMC Clinical Trials Office (CTO). All participants provided informed consent prior to participation in the study.

Design

This was a prospective case series. The study was approved by Western Institutional Review Board (WIRB) and university of Pittsburgh Medical Center Clinical Trials Office (CTO). Participants were recruited from the Sleep Evaluation Center at UPMC, where they have been evaluated and treated for OSA. After obtaining institutional Review Board (IRB) approved informed consent, 27 subjects who met inclusion/exclusion criteria evaluated with BPAP Auto Flex device during attended PSG.

Auto Bi-Level with Bi-Flex

Auto Bi-Level PAP delivers spontaneous Bi-level therapy with automatically adjusting EPAP and IPAP levels. The device is capable of responding to apnea, hypopnea, vibratory snoring, and large air leak events. The Auto Bi-level therapy also incorporates a "pro-active" search algorithm that responds to early indications of airway obstructions. During therapy, the auto Bi-Level PAP device continues to monitor breathing and searches for vibratory snoring, apneas, hypopneas, of flow limitations. The pressure is adjusted in response to an event. Usually, a change occurs over a 15 second period. This approach is based upon a titration protocol that increases EPAP related to obstructive apnea events and increases Pressure Support (PS) based upon obstructive hypopnea, snoring and flow limitation events. The level of pressure support (PS) delivered is determined by the difference between the IPAP and EPAP settings (PS=IPAP-EPAP). In a sleep lab, EPAP is usually adjusted first as the patient goes through various sleep stages and body positions to ensure that obstructive apneas are eliminated under worst-case conditions. PS is then adjusted to eliminate partial airway closure such as hypopneas and snoring. The auto Bi-Level device included a pressure relief feature called Bi-Flex. The Bi-Flex mode provides pressure relief during the latter stages of inspiration and during active exhalation (the beginning part of exhalation). In the Figure 1, comfort feature of Bi-Flex was presented graphically. Bi-Flex levels of 1, 2, or 3

progressively reflect increased pressure relief that take place at the end of inspiration and at the beginning of expiration.
The device was set to deliver between 4 and 25 cmH_2O for both the inspiratory (IPAP) and expiratory (EPAP) positive airway pressures. IPAP and EPAP were adjusted independently as determined by the device's algorithm. The minimum allowable difference between IPAP and EPAP was 2 cmH_2O and a maximum difference was 8 cmH_2O. The device's algorithm determined therapy pressure requirements for the duration of the PSG. Participants received therapy with the auto Bi-Level with Bi-Flex comfort feature.

Polysomnography
Full PSG performed using the SomnoStar Pro™ system (Viasys® Healthcare). Channels monitored and recorded with surface electrodes included electroencephalogram, electrooculogram and submental electromyogram. Arterial oxygen saturation was recorded by digital pulse oximetry. Chest and abdominal effort were recorded using inductance plethysmography. Airflow was recorded with a pressure transducer attached to the Bi-Level device's pressure outlet. Apnea was defined as complete cessation of airflow for at least 10 seconds; hypopnea was defined as a 50% decrease in airflow and a 4% drop in oxygen saturation. American Academy of Sleep Medicine (AASM) sleep scoring criteria was used for scoring the diagnostic PSG (12).

Statistical Analysis
Standard sleep parameters were collected and analyzed. Baseline demographic data was summarized. For continuous variables such as weight, the mean, standard deviation and range was presented. For categorical variables such as gender, the proportion of participants in each category was presented.

Results

The entire study population comprised 82% (22/27) male and 18% (5/27) female participants. The mean age was 54±16 years and BMI (body mass index) was 33.0±9.1 kg/m^2. Participant's demographic and baseline PSG data were shown in Table 1. The mean AHI (apnea hypopnea index) of entire study population obtained from the baseline diagnostic sleep study was 47.0±31.5 events/hour. Thirteen of the 27 participants currently had been using CPAP with a mean pressure of 12.0±3.1 cmH_2O.
Fourteen of the 27 participants were on BPAP treatment. The mean IPAP pressure was 11.4±2.4 cmH_2O and the mean EPAP pressure was 7.6±2.1 cmH_2O. To evaluate performance of BPAPauto device, PSG with BPAPauto was performed. The results obtained from the BPAPauto sleep study were demonstrated in Table 2. The mean total sleep time was 263.4±50.8 and sleep efficiency was 74.5±13.6%. The mean duration of rapid eye movement (REM) sleep was 43.6±25.0 minute. The mean AHI was 2.2±2.5 events/hour. The mean SaO_2 (oxygen saturation) was 94.0±1.8. The mean IPAP pressure required to abolish respiratory events was 14.1±3.4 cmH_2O and that of EPAP pressure was 10.7±3.9 cmH_2O. Figure 2, shows the representative waveform of BPAPauto signal performance.

Discussion

Data obtained from this study showed that BPAPauto is able to determine appropriate Bi-Level positive airway pressure and control oxygen saturation without excessive disruption of sleep. In 1981, nasal continuous positive airway pressure, which acts as a pneumatic splint, was introduced as a treatment of OSA and has been considered the gold standard for treatment of OSA since (13). Several clinical trials have shown that CPAP eliminates apneic and hypopneic events, improve day time function, quality of life, sustained attention and mood and decrease cardiovascular risk factors (14-17). Although highly effective, only half of the patients use CPAP as prescribed(18). Pressure intolerance could be one of the reasons for decreased

Table 1. Subject characteristics and baseline polysomnographic data

Demographical variables	
Age (years)	54±16
Gender (number)	22 Male/5 Female
Body mass index (kg/m^2)	33.9±9.1
AHI in diagnostic PSG (events/hour)	47.0±31.5
Current AHI (events/hour)	6.4±9.7
Mean CPAP pressure (mmHg)	12.0±3.1
BPAP Mean IPAP pressure (mmHg) Mean EPAP pressure (mmHg)	 11.4±2.4 7.6±2.1

AHI: apnea-hypopnea index, PSG: polysomnography, CPAP: continuous positive airway pressure, BPAP: bilevel positive airway pressure, IPAP: inspiratory positive airway pressure, EPAP: expiratory positive airway pressure

Table 2. BPAPauto parameters and its effect on sleep

Respiratory data	
IPAP 90% (cmH_2O)	14.1±3.4
Leak Lpm	35.0±10.0
SaO2 (%)	94.0±1.8
EPAP 90% (cmH_2O)	10.7±3.9
Pressure support (cmH_2O)	3.2±0.8
AHI (events/hour)	2.2±2.5
Sleep parameters	
REM sleep duration (minutes)	46.3±25.0
N2 sleep duration (minutes)	202.8±46.2
N3 sleep duration (minutes)	3.4±5.0
Sleep efficacy (%)	74.5±13.6
Arousal index (events/hour)	7.0±5.1

IPAP 90%: inspiratory positive airway pressure that abolishes 90% of respiratory events, EPAP 90%: expiratory positive airway pressure that abolishes 90% of respiratory events, SaO_2: oxygen saturation, AHI: apnea hypopnea index

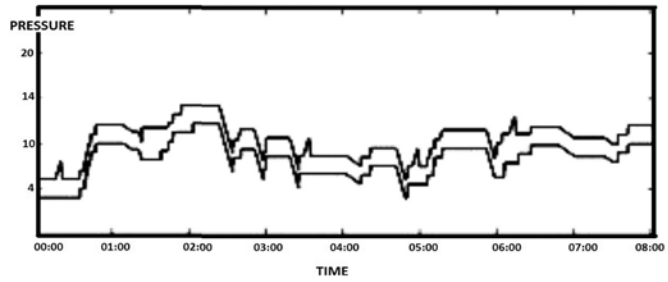

Figure 1. Comfort feature of Bi-Flex presented graphically

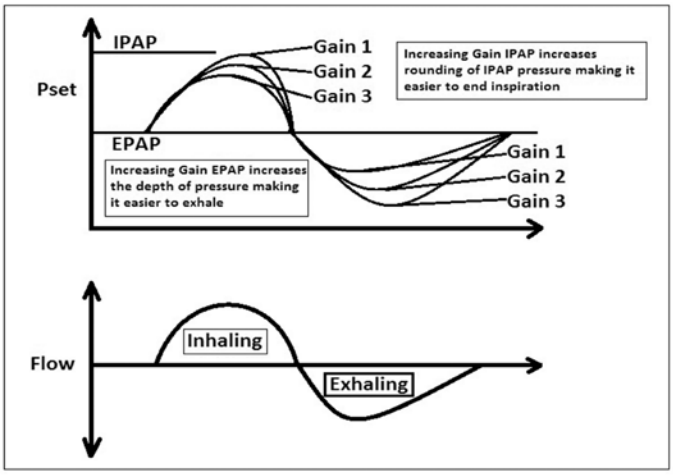

Figure 2. Representative waveform of BPAPauto signal performance

adherence (11,19). Improving patient tolerance of PAP is one of the main driving forces for the development of alternative modes of PAP. A change in PAP mode may dramatically improve adherence in individual patients (5). However studies showed that BPAP or APAP treatments do not result in higher adherence (9,20).

In one study use of C-flex device provided a statistically significant improvement in adherence (21). BPAPauto was developed to potentially increase comfort and adherence to therapy. In a BPAPauto validation study, Wylie et all showed that the BiPAP Auto with Bi-Flex provided adequate clinical resolution of the obstructive apnea and hypopnea events, with lower mean IPAP pressure and the effect on sleep continuity and architecture was comparable to that experienced during manual titration as determined during attended in-laboratory polysomnographic evaluation. In our study, IPAP and EPAP pressures of BPAPauto were higher than those of BPAP pressures though not statistically insignificant. On the other hand, BPAPauto was found to be better in eliminating obstructive apnea and hypoapnea events, and associated with increased sleep efficacy, total sleep time, proportion of deep sleep and REM sleep stages, as well as higher oxygen saturation. It is known that, a number of factors such as body position, sleep stage, nasal patency, ingestion of alcohol or hypnotic agents can affect the level of PAP required to keep upper airway open during sleep (22). Instead of fixed IPAP/EPAP pressures, BPAPauto adjusts to an EPAP and an IPAP that are most comfortable for the patient. The Bi-Flex feature provides pressure relief in the transition period between the end of IPAP, and the beginning of EPAP and allows for a more comfortable delivery of PAP therapy. This mode could potentially be useful in pressure intolerant patients or patients who have considerable variability in the pressure requirement throughout the night (5). This new device could be helpful to increase the adherence of patients to the therapy. The advantages of BPAPauto over other PAP modes remain to be demonstrated.

One of the main limitations of this study is small study population size and lack of a control group. In addition, re-evaluation following titration may have add further important data in terms of clinical assessment.

In conclusion, BPAPauto is able to determine appropriate Bi-Level positive airway pressure and control oxygen saturation without excessive disruption of sleep. Further studies using randomized control design are needed to examine potential roles and advantages of BPAPauto for treatment of OSA.

References

1. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 1993;328:1230-5.
2. Lattimore JD, Celermajer DS, Wilcox I. Obstructive sleep apnea and cardiovascular disease. Journal of the American College of Cardiology 2003;41:1429-37.
3. Indications and standards for use of nasal continuous positive airway pressure (CPAP) in sleep apnea syndromes. American Thoracic Society. Official statement adopted March 1944. Am J Respir Cri Care Med 1994;150:1738-45.
4. Hoffstein V, Viner S, Mateika S, Conway J. Treatment of obstructive sleep apnea with nasal continuous positive airway pressure. Patient compliance, perception of benefits, and side effects. Am Rev Respir Dis 1992;145:841-5.
5. Kakkar RK, Berry RB. Positive airway pressure treatment for obstructive sleep apnea. Chest 2007;132:1057-72.
6. Pepin JL, Krieger J, Rodenstein D, Cornette A, Sforza E, Delguste P, et al. Effective compliance during the first 3 months of continuous positive airway pressure. A European prospective study of 121 patients. Am J Respir Cri Care Med 1999;160:1124-9.
7. Sin DD, Mayers I, Man GC, Pawluk L. Long-term compliance rates to continuous positive airway pressure in obstructive sleep apnea: a population-based study. Chest 2002;121:430-5.
8. Engleman HM, Wild MR. Improving CPAP use by patients with the sleep apnoea/hypopnoea syndrome (SAHS). Sleep medicine reviews 2003;7:81-99.
9. 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 Cri Care Med 1995;151:443-9.
10. Gay P.C, Herold DL, Olson EJ. A randomized, double-blind clinical trial comparing continuous positive airway pressure with a novel bilevel pressure system for treatment of obstructive sleep apnea syndrome. Sleep 2003;26:864-9.

11. Resta O, Guido P, Picca V, Sabato R, Rizzi M, Scarpelli F, et al. Prescription of nCPAP and nBIPAP in obstructive sleep apnoea syndrome: Italian experience in 105 subjects. A prospective two centre study. Respiratory Medicine 1998;92:820-7.
12. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The Report of an American Academy of Sleep Medicine Task Force. Sleep 1999;22:667-89.
13. Sullivan CE, Issa FG, Berthon-Jones M, Eves L. Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. Lancet 1981;1:862-5.
14. Engleman HM, Martin SE, Kingshott RN, Mackay TW, Deary IJ, Douglas NJ. Randomised placebo controlled trial of daytime function after continuous positive airway pressure (CPAP) therapy for the sleep apnoea/hypopnoea syndrome. Thorax 1998;53:341-5.
15. Jenkinson C, Davies RJ, Mullins R, Stradling JR. Comparison of therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: a randomised prospective parallel trial. Lancet 1999;353:2100-5.
16. Gay P, Weaver T, Loube D, Iber C. Evaluation of positive airway pressure treatment for sleep related breathing disorders in adults. Sleep 2006;29:381-401.
17. Campos-Rodriguez F, Perez-Ronchel J, Grilo-Reina A, Lima-Alvarez J, Benitez MA, Almeida-Gonzalez C. Long-term Effect of Continuous Positive Airway Pressure on BP in Patients With Hypertension and Sleep Apnea. Chest 2007;132:1847-52.
18. Weaver TE. Adherence to positive airway pressure therapy. Current opinion in pulmonary medicine 2006;12:409-13.
19. Kalan A, Kenyon GS, Seemungal TA, Wedzicha JA. Adverse effects of nasal continuous positive airway pressure therapy in sleep apnoea syndrome. J Laryngol Oto 1999;113:888-92.
20. 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;27:249-53.
21. Aloia MS, Stanchina M, Arnedt JT, Malhotra A, Millman RP. Treatment adherence and outcomes in flexible vs standard continuous positive airway pressure therapy. Chest 2005;127:2085-93.
22. d'Ortho MP, Grillier-Lanoir V, Levy P, Goldenberg F, Corriger E, Harf A, et al. Constant vs. automatic continuous positive airway pressure therapy: home evaluation. Chest 2000;118:1010-7.