

Continuous positive airway pressure for the treatment of obstructive sleep apnea

Presiunea pozitivă continuă a căilor aeriene pentru tratamentul apneei în somn de tip obstructiv

Fariz Nurwidya¹, Agus Dwi Susanto¹, Dafsa A Juzar², Isao Kobayashi³, Faisal Yunus¹

1. Department of Pulmonology and Respiratory Medicine, University of Indonesia Faculty of Medicine, Jakarta, Indonesia

2. Department of Cardiology and Vascular Medicine, University of Indonesia Faculty of Medicine, Jakarta, Indonesia

3. Department of Respiratory Medicine, Juntendo University Graduate School of Medicine, Tokyo, Japan

Corresponding author:

Fariz Nurwidya, MD, PhD.

Persahabatan General Hospital, Jalan Persahabatan Raya No. 1, Rawamangun Jakarta 13220, Indonesia.

E-mail: fariz.nurwidya@gmail.com

Abstract

Obstructive sleep apnea (OSA) is a recurrent episode of partial or complete upper airway obstruction during sleep despite ongoing respiratory efforts and is implicated as the risk factor of cardiovascular disease. The OSA syndrome is typified by recurring partial or total occlusion of the pharynx, sleep fragmentation, episodes of gasping, and, eventually, daytime sleepiness. If it is left untreated, OSA syndrome can cause hypertension, coronary artery disease, congestive heart disease, insulin resistance and death. In this review, we describe the pathogenesis and diagnosis of OSA. We also focused on the continuous positive airway pressure (CPAP) as the main therapy for OSA. CPAP has been shown to provide benefit for not only respiratory system, but also for cardiovascular system and metabolic system. Finally, we discussed briefly about the issue of adherence of using CPAP that could contribute to lower compliance in patient with OSA. **Keyword:** obstructive sleep apnea, continuous positive airway pressure

Rezumat

Apneea în somn de tip obstructiv reprezintă o succesiune de obstrucții parțiale sau complete a căilor aeriene superioare, în condițiile existenței efortului respirator și constituie un factor de risc pentru bolile cardiovasculare. Sindromul de apnee în somn de tip obstructiv (SASO) este caracterizat prin ocuzie recurentă parțială sau totală a faringelui, fragmentarea somnului, episoade de gasping, și, în cele din urmă, somnolență în timpul zilei. În cazul în care este lăsat netratat, SASO poate duce la hipertensiune arterială, boli coronariene, boli cardiace congestive, rezistența la insulină și deces. În această recenzie, vom descrie patogeneza și diagnosticul SASO. De asemenea, ne-am concentrat pe presiunea pozitivă continuă a căilor respiratorii (CPAP), ca principală terapie pentru SASO. S-a demonstrat că CPAP oferă beneficii nu numai pentru sistemul respirator, dar, de asemenea, pentru sistemul cardiovascular și sistemul metabolic. În final, am discutat pe scurt despre problema aderenței la CPAP, care ar putea contribui la complianța redusă a pacientului cu SASO. **Cuvinte-cheie:** apnee obstructivă în somn, presiune pozitivă continuă a căilor aeriene

Abbreviation: AHI, apnea-hypopnea index; APAP, automatic self-adjusting positive airway pressure; BiAP, bilevel positive airway pressure; CPAP, continuous positive airway pressure; MWT, maintenance of wakefulness test; ESS, Epworth Sleepiness Scale; OSA, obstructive sleep apnea; RDI, respiratory disturbance index; SAS, sleep apnea syndrome.

Introduction

Sleep is key to maintaining the body's vital functions. The American Academy of Sleep Medicine (AASM) and Sleep Research Society (SRS) stated that sleeping less than 7 hours per night on a daily basis resulted in increased risk of weight gain and obesity, diabetes, hypertension, heart disease, stroke, depression, death, impaired immune function, pain, impaired performance, increased errors, and greater risk of accidents⁽¹⁻³⁾. As a common sleep related disorder, obstructive sleep apnea (OSA) is becoming a significant health problem worldwide. In the general adult population, the prevalence of OSA defined by ≥ 5 apnea and hypopnea events per hour of sleep associated with excessive sleepiness is approximately 3-7% in men and 2-5% in women⁽⁴⁾. OSA was commonly found in people with excess body weight^(5,6), advancing age⁽⁷⁾, and men⁽⁸⁾. The other risk factors that have been studied contributing in the development of OSA are family history⁽⁹⁾, while modifiable risk factors of OSA include nasal congestion, smoking, alcohol, and estrogen depletion in menopause⁽¹⁰⁾. Recent evidence suggests that increased size of the pharyngeal lymphoid tissue, instead of enlargement of the upper airway soft tissue structures, is the primary anatomic risk

factor for OSAS in obese adolescents⁽¹¹⁾. The incidence of OSA in snoring patients is reported in the literature to range from 20% to 70%⁽¹²⁾. Moreover, snoring intensity correlates with the severity of OSA⁽¹³⁾. However, other studies have shown that nocturnal gasping or choking is the most reliable indicator of obstructive sleep apnea, whereas snoring is not very specific⁽¹⁴⁾. Several symptoms are described in obstructive sleep apnea OSA, including excessive daytime sleepiness, depressive mood, neurocognitive dysfunction, low level of physical activity and reduced quality of life⁽¹⁵⁾. Strikingly, there are health related conditions implicated with OSA, such as motor vehicle accidents, hypertension, insulin resistance, and cardiovascular diseases, are now emerging⁽¹⁶⁾.

Definitions

By definition, sleep apnea is a cessation of airflow at the nose and mouth during sleep⁽¹⁷⁾. Sleep apnea syndrome (SAS) is characterized by repetitive episodes of cessation of breathing during sleep, resulting in hypoxemia and sleep disruption⁽¹⁸⁾. There are two types of SAS: obstructive sleep apnea syndrome (OSAS) and central sleep apnea syndrome (CSAS). In OSA, airflow ceases because of occlusion of the upper

airway at the oropharyngeal level despite continued activation of the inspiratory muscle, meanwhile in CSA, airflow ceases because drive to respiratory muscle is transiently abolished⁽¹⁷⁾. OSA is the occurrence of an average five or more episodes of obstructive respiratory events per hour of sleep with either sleep related symptoms or comorbidities or ≥ 15 such episodes without any sleep related symptoms or comorbidities⁽¹⁹⁾. OSAS is defined as OSA associated with daytime symptoms, most often excessive sleepiness⁽²⁰⁾.

Pathogenesis of OSA

OSA is a common disorder characterized by repetitive collapse or obstruction of the pharyngeal airway during sleep⁽²¹⁾. The most common site of obstruction was at the level of the oropharynx, with extension to the laryngopharynx⁽²²⁾. Control of pharyngeal patency is a complex process relating primarily to basic anatomy and the activity of many pharyngeal dilator muscles and control of these muscles is regulated by a number of processes including respiratory drive, negative pressure reflexes, and state (sleep) effects⁽²³⁾. Individual variability in several phenotypic characteristics may ultimately determine who develops apnea and how severe the apnea will be. These include: **(1)** upper airway anatomy, **(2)** the ability of upper airway dilator muscles to respond to rising intra-pharyngeal negative pressure and increasing CO₂ during sleep, **(3)** arousal threshold in response to respiratory stimulation, and **(4)** loop gain (ventilatory control instability)⁽²⁴⁾. More than half of OSA patients can be classified as supine-related OSA, which is being attributable to unfavorable airway geometry, reduced lung volume, and an inability of airway dilator muscles to adequately compensate as the airway collapses⁽²⁵⁾.

If it is left untreated, OSA could cause serious complications related to heart and vascular diseases, such as hypertension⁽²⁶⁾, coronary heart disease⁽²⁷⁾, stroke⁽²⁸⁾, and congestive heart disease⁽²⁹⁾. The acute haemodynamic and autonomic perturbations that accompany obstructive apneas during sleep, with associated repeated arousals and intermittent hypoxemia, appear to result in sustained hypertension⁽²⁶⁾. OSA appears to predispose individuals to autonomic imbalance characterized by increased sympathetic tone and altered baroreflex mechanisms as well as vascular dysfunction⁽³⁰⁾. As for the risk of arrhythmia, it is said that subjects with severe OSA often have a much higher prevalence of atrial fibrillation, non-sustained ventricular tachycardia and complex ectopic excitation compared with individuals without OSA⁽³¹⁾.

Diagnosis of OSA

According to AASM, patients with the following conditions are at high risk for OSA and therefore should be evaluated for OSA symptoms: obesity (BMI > 35); congestive heart failure; atrial fibrillation; treatment of refractory hypertension; type 2 diabetes; nocturnal dysrhythmias; stroke; pulmonary hypertension; high-risk driving populations, and; preoperative for bariatric surgery⁽³²⁾. The gold standard for the diagnosis of OSA is polysomnography, a full overnight sleep study^(33,34). In Indonesia, especially in major cities, there are emerging sleep centers equipped with polysomnography facility, both in government hospitals and private-owned hospitals. Components of polysomnography include electroencephalogram, electro-

myogram, electro-oculogram, respiration (flow, effort, oxygen saturation), snoring, and continuous-lead ECG⁽³⁵⁾. Polysomnography measures several sleep variables, one of which is the apnea-hypopnea index (AHI)⁽³⁶⁾. The AHI is defined as the sum of apneas and hypopneas per hour of sleep; apnea is defined as the absence of airflow for ≥ 10 seconds; and hypopnea is defined as reduction in respiratory effort with $\geq 4\%$ oxygen desaturation⁽³⁶⁾. The AHI has been widely used to diagnose OSA. Generally, an AHI of more than five events per hour of sleep is considered abnormal and the patient is considered to have a sleep disorder. An abnormal AHI accompanied by excessive daytime sleepiness is the hallmark for OSA diagnosis⁽³⁶⁾. Excessive daytime sleepiness is most frequently assessed using the Epworth Sleepiness Scale (ESS), a questionnaire that has participants rate his or her likelihood of falling asleep in eight different daily situations on a scale of 0 to 24, with higher scores indicating greater sleepiness (ESS ≤ 7 , normal sleepiness)⁽³⁷⁾. Maintenance of Wakefulness Test (MWT) measures the capacity of patient to remain awake in conditions ideal for falling asleep, i.e. quiet darkened room, and is useful in evaluating disability from daytime sleepiness^(38,39). Portable sleep monitors may represent a feasible method for detecting OSA in high-risk urban minority populations⁽⁴⁰⁾. To determine the site of obstruction, for example to assist surgical intervention, several diagnostic procedures might be considered including lateral cephalometric radiographs, asleep fluoroscopy, CT, MRI, asleep and awake endoscopy, upper airway manometry, and acoustic reflection techniques⁽⁴¹⁾.

Management of OSA

The first-line treatment for OSA, continuous positive airway pressure (CPAP), is highly efficacious in reducing sleep-disordered breathing events⁽⁴²⁾. Oral appliances are indicated for use in patients with mild to moderate OSA who prefer oral appliances to CPAP, or who do not respond to CPAP or who fail treatment attempts with PAP or behavioural measures, while surgical treatment is recommended in patients who have failed or are intolerant to PAP therapy⁽⁴³⁾. Therefore, CPAP is recommended as the first-line and oral appliances as second-line treatments for severe OSA patients⁽⁴⁴⁾. Other interventions may help patients with OSA, such as lateral sleep^(45,46), exercise^(47,48), weight reduction^(49,50), upper airway surgery⁽⁵¹⁾.

In hypertensive patient with OSA, CPAP should be used in combination with antihypertensive medications because CPAP has the additional benefits of restoring nocturnal dipping and improving arterial stiffness⁽⁵²⁾. In one study, CPAP for 3 weeks were effective in providing additional decrease in office blood pressure (BP), ambulatory BP monitoring, central BP, and augmentation index, together with an improvement in arterial stiffness parameters, such as carotid-femoral pulse wave velocity (cfPWV) and ambulatory arterial stiffness index (AASI)⁽⁵³⁾.

Principles of positive airway pressure: Focus on continuous positive airway pressure

Currently, PAP devices come in three forms: **(1)** continuous positive airway pressure (CPAP), **(2)** bilevel positive airway pressure (BiPAP), and **(3)** automatic self-adjusting positive airway pressure (APAP)⁽⁵⁴⁾. The physiological effects of CPAP therapy are as follows: splints the upper airway,

achieves positive intrathoracic pressure, decreases venous return, increases lung volume, decreases after-load, and increases cardiac output⁽⁵⁵⁾.

The pressure required to treat OSA can be determined during an in-laboratory titration study or the pressure can be adjusted automatically using device algorithms based on the characteristics of the airflow waveform to minimize abnormal breathing events⁽⁵⁶⁾. These automatically adjusted positive airway pressure (APAP) devices are available for CPAP (Auto-CPAP) and BiPAP (Auto-BiPAP)⁽⁵⁷⁾. The American Academy of Sleep Medicine recommended the following steps during CPAP titrations⁽⁵⁸⁾: **(1)** Patient should be well informed about the purpose of CPAP, including hands-on demonstration, careful mask fitting, and acclimatization before titration. **(2)** CPAP should be increased until the apneas, hypopneas, respiratory effort-related arousals (RERAs), and snoring are eliminated or the maximum CPAP is reached. **(3)** The minimum starting pressure should be 4 cm H₂O. **(4)** The recommended maximum CPAP should be 15 cm H₂O for patients < 12 years, and 20 cm H₂O for patients ≥ 12 years. **(5)** CPAP should be increased by 1 cm H₂O per 5 min, with the goal of eliminating obstructive respiratory events. **(6)** CPAP should be increased from any CPAP level if at least 1 obstructive apnea is observed for patients < 12 years, or if at least 2 obstructive apneas in patients ≥ 12 years. **(7)** CPAP should be increased from any CPAP level if at least 1 hypopnea is observed for patients < 12 years, or if at least 3 hypopneas in patients ≥ 12 years. **(8)** CPAP should be increased from any CPAP level if at least 3 RERAs are observed for patients < 12 years, or if at least 5 RERAs are observed for patients ≥ 12 years. **(9)** CPAP may be increased from any CPAP level if at least 1 min of loud or unambiguous snoring is observed for patients < 12 years, or if at least 3 min for patients ≥ 12 years. **(10)** If the patient is uncomfortable or intolerant of high pressures on CPAP, the patient may be tried on BiPAP. If there are continued obstructive respiratory events at 15 cm H₂O of CPAP during the titration study, the patient may be switched to BiPAP. **(11)** The pressure of CPAP should reflect control of the patient's obstructive respiration by a low (preferably < 5 per hour) AHI, SpO₂ above 90%, and with a minimum leak. **(12)** An optimal titration reduces AHI < 5 for at least 15-min duration and should include supine uninterrupted REM sleep. **(13)** A good titration reduces AHI ≤ 10 and should include supine uninterrupted REM sleep. **(14)** An adequate titration does not reduce the AHI ≤ 10 but reduces the AHI by 75% from baseline (especially in severe OSA patients), or one in which the titration grading criteria for optimal or good are met with the exception that supine REM sleep did not occur at the selected pressure. **(15)** An unacceptable titration is one that does not meet any one of the above grades. **(16)** A repeat CPAP titration study should be consid-

ered if the initial titration does not achieve a grade of optimal or good and, if it is a split-night PSG study, it fails to meet AASM criteria (i.e., titration duration should be > 3 hr). To obtain optimal benefit, average use is about 5 to 6 h per night in most compliant patients⁽⁵⁹⁾.

Benefits of CPAP

When properly titrated, CPAP minimize the number of sleep-related breathing disorder events, often producing dramatic results, such as normalized sleep-related breathing, sleep microstructure may improve, and the patient may awaken feeling refreshed for the first time in years⁽⁶⁰⁾. The use of CPAP resulted in several benefits for organs system. For circulation system, CPAP has been shown to provide better blood pressure⁽⁶¹⁾, although it did not change the cardiac functional or structural parameters measured by echocardiogram⁽⁶²⁾. In metabolic disorders, CPAP increase the antioxidant level and reduce the oxidative stress⁽⁶³⁾. In respiratory system, CPAP implicated in improvement of apnea-hypopnea index (AHI), oxygen desaturation index⁽⁶⁴⁾. CPAP therapy also improves quality of life, lessens depressive symptoms, and increased neurocognitive functions^(65,66,67).

Adherence to therapy is of major importance because CPAP is being used long term on a daily basis about 5-6 hours per night⁽⁶⁸⁾. With adherence rates ranging from 30-60%, it can be a significant limiting factor in treating OSA, reducing the overall effectiveness of the treatment and leaving many OSA patients at heightened risk for comorbid conditions⁽⁶⁹⁾. To enhance the patient compliance in using CPAP, the following aspect should be considered: education about the consequences of untreated OSA and the benefits of CPAP; assessment of social, psychological, and demographic factors that may contribute to difficulty complying; addressing side effects such as nasal symptoms and equipment usability issues⁽⁷⁰⁾.

Conclusions

OSA is a serious health problem because it can cause various diseases. Accumulating evidence revealed that OSA is associated with hypertension, arrhythmia, coronary artery disease, congestive heart failure, and stroke. The diagnosis of OSA requires polysomnography examination that measures apnea-hypopnea index (AHI) or respiratory disturbance index (RDI). The implications of daytime sleepiness due to OSA should be evaluated using well-established test including Maintenance of Wakefulness Test (MWT) and Epworth Sleepiness Scale (ESS). CPAP, although long-term compliance with CPAP remains to be resolved, is still the main therapy for OSA and has provided benefits in organ systems such as cardiovascular system, respiratory systems and neurocognitive functions. ■

References

1. Watson NF, Badr MS, Belenky G, *et al.* Recommended Amount of Sleep for a Healthy Adult: A Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society. *Sleep* 2015; 38: 843-4.
2. Watson NF, Badr MS, Belenky G, *et al.* Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society on the Recommended Amount of Sleep for a Healthy Adult: Methodology and Discussion. *J Clin Sleep Med* 2015; 11: 931-52.
3. Watson NF, Badr MS, Belenky G, *et al.* Recommended Amount of Sleep for a Healthy Adult: A Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society. *J Clin Sleep Med* 2015; 11: 591-2.
4. Lurie A. Obstructive sleep apnea in adults: epidemiology, clinical presentation, and treatment options. *Adv Cardiol* 2011; 46: 1-42.
5. Alonso-Alvarez ML, Cordero-Guevara JA, Teran-Santos J, *et al.* Obstructive sleep apnea in obese community-dwelling children: the NANOS study. *Sleep* 2014; 37: 943-9.
6. Dacal Quintas R, Tumbreiro Novoa M, Alves Perez MT, Santalla Martinez ML, Acuna Fernandez A, Marcos Velazquez P. Obstructive sleep apnea in normal weight patients: characteristics and comparison with overweight and obese patients. *Arch Bronconeumol* 2013; 49: 513-7.
7. Foley DJ, Monjan AA, Brown SL, Simonsick EM, Wallace RB, Blazer DG. Sleep complaints among elderly persons: an epidemiologic study of three communities. *Sleep* 1995; 18: 425-32.

References

8. Young T, Skatrud J, Peppard PE. Risk factors for obstructive sleep apnea in adults. *Jama* 2004; 291: 2013-6.
9. McNamara F, Sullivan CE. Obstructive sleep apnea in infants: relation to family history of sudden infant death syndrome, apparent life-threatening events, and obstructive sleep apnea. *J Pediatr* 2000; 136: 318-23.
10. Young T, Peppard PE, Gottlieb DJ. Epidemiology of obstructive sleep apnea: a population health perspective. *Am J Respir Crit Care Med* 2002; 165: 1217-39.
11. Schwab RJ, Kim C, Bagchi S, et al. Understanding the anatomic basis for obstructive sleep apnea syndrome in adolescents. *Am J Respir Crit Care Med* 2015; 191: 1295-309.
12. Keropian B, Murphy N. The prevalence of OSA in snorers presenting with various chief complaints: a pilot study. *Cranio* 2014; 32: 217-8.
13. Maimon N, Hanly PJ. Does snoring intensity correlate with the severity of obstructive sleep apnea? *J Clin Sleep Med* 2010; 6: 475-8.
14. Myers KA, Mrkobrada M, Simel DL. Does this patient have obstructive sleep apnea?: The Rational Clinical Examination systematic review. *Jama* 2013; 310: 731-41.
15. Verwimp J, Ayme L, Bruyneel M. Correlation between sleep parameters, physical activity and quality of life in somnolent moderate to severe obstructive sleep apnea adult patients. *Sleep Breath* 2013; 17: 1039-46.
16. Lee W, Nagubadi S, Kryger MH, Mokhlesi B. Epidemiology of Obstructive Sleep Apnea: a Population-based Perspective. *Expert Rev Respir Med* 2008; 2: 349-64.
17. Bradley T, Philipson E. Sleep Disorder. In: Mason R, Murray J, Broaddus V, Nadel J, eds. *Murray and Nadel's Textbook of Respiratory Medicine*. Philadelphia: Elsevier Saunders, 2005; 2093.
18. Banno K, Kryger MH. Sleep apnea: clinical investigations in humans. *Sleep Med* 2007; 8: 400-26.
19. Sharma SK, Katoch VM, Mohan A, et al. Consensus & Evidence-based INOSA Guidelines 2014 (First edition). *Indian J Chest Dis Allied Sci* 2015; 57: 48-64.
20. Sharma SK, Katoch VM, Mohan A, et al. Consensus and evidence-based Indian initiative on obstructive sleep apnea guidelines 2014 (first edition). *Lung India* 2015; 32: 422-34.
21. Edwards BA, Wellman A, Sands SA, et al. Obstructive sleep apnea in older adults is a distinctly different physiological phenotype. *Sleep* 2014; 37: 1227-36.
22. Rama AN, Tekwani SH, Kushida CA. Sites of obstruction in obstructive sleep apnea. *Chest* 2002; 122: 1139-47.
23. White DP, Younes MK. Obstructive sleep apnea. *Compr Physiol* 2012; 2: 2541-94.
24. White DP. Pathogenesis of obstructive and central sleep apnea. *Am J Respir Crit Care Med* 2005; 172: 1363-70.
25. Joosten SA, O'Driscoll DM, Berger PJ, Hamilton GS. Supine position related obstructive sleep apnea in adults: pathogenesis and treatment. *Sleep Med Rev* 2014; 18: 7-17.
26. Phillips CL, Cistulli PA. Obstructive sleep apnea and hypertension: epidemiology, mechanisms and treatment effects. *Minerva Med* 2006; 97: 299-312.
27. Wolf J, Lewicka J, Narkiewicz K. Obstructive sleep apnea: an update on mechanisms and cardiovascular consequences. *Nutr Metab Cardiovasc Dis* 2007; 17: 233-40.
28. Lyons OD, Ryan CM. Sleep Apnea and Stroke. *Can J Cardiol* 2015; 31: 918-27.
29. Badran M, Ayas N, Laher I. Cardiovascular Complications of Sleep Apnea: Role of Oxidative Stress. *Oxidative Medicine and Cellular Longevity* 2014; 2014: 10.
30. Das AM, Khayat R. Hypertension in obstructive sleep apnea: risk and therapy. *Expert Rev Cardiovasc Ther* 2009; 7: 619-26.
31. Thomas JJ, Ren J. Obstructive sleep apnoea and cardiovascular complications: perception versus knowledge. *Clinical and Experimental Pharmacology and Physiology* 2012; 39: 995-1003.
32. Epstein LJ, Kristo D, Strollo PJ, Jr, et al. Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. *J Clin Sleep Med* 2009; 5: 263-76.
33. Gasparini G, Vicini C, De Benedetto M, et al. Diagnostic Accuracy of Obstructive Airway Adult Test for Diagnosis of Obstructive Sleep Apnea. *Biomed Res Int* 2015; 2015: 915185.
34. Kushida CA, Littner MR, Morgenthaler T, et al. Practice parameters for the indications for polysomnography and related procedures: an update for 2005. *Sleep* 2005; 28: 499-521.
35. Somers VK, White DP, Amin R, et al. Sleep apnea and cardiovascular disease: an American Heart Association/American College of Cardiology Foundation Scientific Statement from the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council on Cardiovascular Nursing. In collaboration with the National Heart, Lung, and Blood Institute National Center on Sleep Disorders Research (National Institutes of Health). *Circulation* 2008; 118: 1080-111.
36. Polysomnography in patients with obstructive sleep apnea: an evidence-based analysis. *Ont Health Technol Assess Ser* 2006; 6: 1-38.
37. CADTH Rapid Response Reports. In: *CPAP Treatment for Adults with Obstructive Sleep Apnea: Review of the Clinical and Cost-Effectiveness and Guidelines*. Ottawa (ON): Canadian Agency for Drugs and Technologies in Health Copyright (c) 2013 Canadian Agency for Drugs and Technologies in Health, 2013.
38. Philip P, Sagaspe P, Taillard J, et al. Maintenance of Wakefulness Test, obstructive sleep apnea syndrome, and driving risk. *Ann Neurol* 2008; 64: 410-6.
39. Poceta JS, Timms RM, Jeong DU, Ho SL, Erman MK, Mittleman MM. Maintenance of wakefulness test in obstructive sleep apnea syndrome. *Chest* 1992; 101: 893-7.
40. Nickerson J, Lee E, Nedelman M, Aurora RN, Krieger A, Horowitz CR. Feasibility of portable sleep monitors to detect obstructive sleep apnea (OSA) in a vulnerable urban population. *J Am Board Fam Med* 2015; 28: 257-64.
41. Thakkar K, Yao M. Diagnostic studies in obstructive sleep apnea. *Otolaryngol Clin North Am* 2007; 40: 785-805.
42. Eckert DJ, White DP, Jordan AS, Malhotra A, Wellman A. Defining phenotypic causes of obstructive sleep apnea. Identification of novel therapeutic targets. *Am J Respir Crit Care Med* 2013; 188: 996-1004.
43. Sharma SK, Katoch VM, Mohan A, et al. Consensus & evidence-based INOSA Guidelines 2014 (first edition). *Indian J Med Res* 2014; 140: 451-68.
44. Kushida CA, Morgenthaler TI, Littner MR, et al. Practice parameters for the treatment of snoring and Obstructive Sleep Apnea with oral appliances: an update for 2005. *Sleep* 2006; 29: 240-3.
45. Joosten SA, Edwards BA, Wellman A, et al. The Effect of Body Position on Physiological Factors that Contribute to Obstructive Sleep Apnea. *Sleep* 2015; 38: 1469-78.
46. Oksenberg A, Gadoth N. Are we missing a simple treatment for most adult sleep apnea patients? The avoidance of the supine sleep position. *J Sleep Res* 2014; 23: 204-10.
47. Iftikhar IH, Kline CE, Youngstedt SD. Effects of exercise training on sleep apnea: a meta-analysis. *Lung* 2014; 192: 175-84.
48. Smith SS, Doyle G, Pascoe T, Douglas JA, Jorgensen G. Intention to exercise in patients with obstructive sleep apnea. *J Clin Sleep Med* 2007; 3: 689-94.
49. Tuomilehto H, Seppa J, Uusitupa M, et al. The impact of weight reduction in the prevention of the progression of obstructive sleep apnea: an explanatory analysis of a 5-year observational follow-up trial. *Sleep Med* 2014; 15: 329-35.
50. Mitchell LJ, Davidson ZE, Bonham M, O'Driscoll DM, Hamilton GS, Truby H. Weight loss from lifestyle interventions and severity of sleep apnoea: a systematic review and meta-analysis. *Sleep Med* 2014; 15: 1173-83.
51. Won CHJ, Li KK, Guilleminault C. Surgical Treatment of Obstructive Sleep Apnea. *Proceedings of the American Thoracic Society* 2008; 5: 193-9.
52. Denker MG, Cohen DL. Use of continuous positive airway pressure for sleep apnea in the treatment of hypertension. *Curr Opin Nephrol Hypertens* 2014; 23: 462-7.
53. Litvin AV, Sukmarova ZN, Elfimova EM, et al. Effects of CPAP on "vascular" risk factors in patients with obstructive sleep apnea and arterial hypertension. *Vasc Health Risk Manag* 2013; 9: 229-35.
54. Kushida CA, Littner MR, Hirshkowitz M, et al. Practice parameters for the use of continuous and bilevel positive airway pressure devices to treat adult patients with sleep-related breathing disorders. *Sleep* 2006; 29: 375-80.
55. Antonescu-Turcu A, Parthasarathy S. CPAP and bi-level PAP therapy: new and established roles. *Respir Care* 2010; 55: 1216-29.
56. Kushida CA, Berry RB, Blau A, et al. Positive airway pressure initiation: a randomized controlled trial to assess the impact of therapy mode and titration process on efficacy, adherence, and outcomes. *Sleep* 2011; 34: 1083-92.
57. Berry RB, Parish JM, Hartse KM. The use of auto-titrating continuous positive airway pressure for treatment of adult obstructive sleep apnea. *An American Academy of Sleep Medicine review*. *Sleep* 2002; 25: 148-73.
58. Kushida CA, Chediak A, Berry RB, et al. Clinical guidelines for the manual titration of positive airway pressure in patients with obstructive sleep apnea. *J Clin Sleep Med* 2008; 4: 157-71.
59. Weaver TE, Maislin G, Dinges DF, et al. Relationship between hours of CPAP use and achieving normal levels of sleepiness and daily functioning. *Sleep* 2007; 30: 711-9.
60. Hirshkowitz M, Sharafkhaneh A. Positive airway pressure therapy of OSA. *Semin Respir Crit Care Med* 2005; 26: 68-79.
61. Sanchez-de-la-Torre M, Khalyfa A, Sanchez-de-la-Torre A, et al. Precision Medicine in Patients With Resistant Hypertension and Obstructive Sleep Apnea: Blood Pressure Response to Continuous Positive Airway Pressure Treatment. *J Am Coll Cardiol* 2015; 66: 1023-32.
62. Craig S, Kyliantiras I, Kohler M, et al. Effect of CPAP on Cardiac Function in Minimally Symptomatic Patients with OSA: Results from a Subset of the MOSAIC Randomized Trial. *J Clin Sleep Med* 2015; 11: 967-73.
63. S K, C B, A S, K R. Effect of Short Term CPAP Therapy in Obstructive Sleep Apnea Patients with Metabolic Syndrome. *J Clin Diagn Res* 2015; 9: Cc07-10.
64. Yang MC, Huang YC, Lan CC, Wu YK, Huang KF. Beneficial Effects of Long-Term CPAP Treatment on Sleep Quality and Blood Pressure in Adherent Subjects With Obstructive Sleep Apnea. *Respir Care* 2015; 60: 1810-8.
65. Diamanti C, Manali E, Ginieri-Coccosis M, et al. Depression, physical activity, energy consumption, and quality of life in OSA patients before and after CPAP treatment. *Sleep Breath* 2013; 17: 1159-68.
66. Kushida CA, Nichols DA, Holmes TH, et al. Effects of continuous positive airway pressure on neurocognitive function in obstructive sleep apnea patients: The Apnea Positive Pressure Long-term Efficacy Study (APPLES). *Sleep* 2012; 35: 1593-602.
67. Antic NA, Catchside P, Buchan C, et al. The effect of CPAP in normalizing daytime sleepiness, quality of life, and neurocognitive function in patients with moderate to severe OSA. *Sleep* 2011; 34: 111-9.
68. Garvey JF, McNicholas WT. Continuous positive airway pressure therapy: new generations. *Indian J Med Res* 2010; 131: 259-66.
69. Weaver TE, Sawyer AM. Adherence to continuous positive airway pressure treatment for obstructive sleep apnoea: implications for future interventions. *Indian J Med Res* 2010; 131: 245-58.
70. Russell T. Enhancing adherence to positive airway pressure therapy for sleep disordered breathing. *Semin Respir Crit Care Med* 2014; 35: 604-12.