International Journal of
Pulmonary & Respiratory Sciences
ISSN: 2573-2234

Juniper PUBLISHERS key to the Researchers

Review Article
Volume 7 Issue 3 - September 2024
DOI: 10.19080/IJOPRS.2024.07.555713

Int J Pul & Res Sci

Long-Term Management of Sleep Apnea-Hypopnea Syndrome: Efficacy and Challenges of Continuous Positive Airway Pressure Therapy

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Submission: August 30, 2024; **Published:** September 06, 2024

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Abstract

Obstructive Sleep Apnea-Hypopnea Syndrome (OSAHS) is a prevalent condition characterized by intermittent upper airway obstruction during sleep, leading to significant health issues, including cardiovascular disease, metabolic syndrome, and neurodegenerative disorders. The primary treatment for OSAHS is Continuous Positive Airway Pressure (CPAP) therapy, which maintains airway patency through a continuous flow of air, effectively reducing apnea-hypopnea indices, improving sleep quality, and lowering cardiovascular risks. Despite its efficacy, adherence to CPAP therapy remains a challenge, with factors such as device discomfort, mask fit issues, and psychological barriers affecting patient compliance. Technological advancements, including smart CPAP devices with auto-adjusting pressure and integrated humidifiers, have improved patient comfort and adherence. Enhanced mask designs and data-tracking capabilities further support personalized treatment approaches. Alternative treatments, such as Mandibular Advancement Devices (MADs), Tongue Retaining Devices (TRDs), and Hypoglossal Nerve Stimulator Therapy (HGNS), offer options for patients intolerant to CPAP. Surgical interventions and bariatric surgery provide additional strategies, particularly for severe cases or patients with comorbid obesity. Pharmacological treatments, including Modafinil and acetazolamide, address residual symptoms and comorbid conditions. Addressing the multifactorial barriers to CPAP adherence through patient education, tailored strategies, and ongoing research is crucial for optimizing treatment outcomes. Future studies are needed to better understand the long-term impacts of untreated mild OSAHS and to develop effective, cost-efficient interventions.

Keywords: Obstructive Sleep Apnea-Hypopnea Syndrome (OSAHS); Continuous Positive Airway Pressure (CPAP); Adherence and Technological Advances; National Health Insurance; Dream Enactment Behavior

Abbreviations: OSAHS: Obstructive Sleep Apnea-Hypopnea Syndrome; OSA: Obstructive Sleep Apnea; AHI: Apnea-Hypopnea Index; CPAP: Continuous Positive Airway Pressure; PEEP: Positive End-Expiratory Pressure; NREM: Non-Rapid Eye Movement; MMA: Maxillomandibular Advancement; UPPP: Uvulopalatopharyngoplasty; MRAs: Mineralocorticoid Receptor Antagonists; ACEIs: Angiotensin-Converting Enzyme Inhibitors; ARBs: Angiotensin Receptor Blockers; CSA: Central Sleep Apnea; TRDs: Tongue Retaining Devices; HGNS: Hypoglossal Nerve Stimulator; NMES: Neuromuscular Electrical Stimulation; SAHOS: Sleep Apnea-Hypopnea Obstructive Syndrome; MADs: Mandibular Advancement Devices; QOL: Quality of Life; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure

Introduction

The American Association of Sleep Medicine defines obstructive sleep apnea/hypopnea syndrome (OSAHS) as a ≥ 30% decrease in airflow associated with a ≥ 3% reduction in the oxygen saturation or arousal (H3A) for diagnosis of obstructive sleep apnea (OSA) in adults [1]. It includes a broad spectrum of etiologies resulting in upper airway collapse and obstruction during sleep inducing cessation of breathing, abnormally slow or shallow breathing, snoring and apnea (complete cessation of breathing) [2]. The reported prevalence of OSAHS, which varies from 3.3 - 15% in different studies, signifies that this condition is not uncommon and can significantly affect the male population [3-5].

OSAHS has been associated with multiple metabolic and aging-associated diseases, including hypertension, metabolic syndrome, stroke, arrhythmias, coronary heart disease, Alzheimer's disease, Parkinson's disease, neurodegenerative disorders, and epilepsy, among others [6,7]. One proposed mechanism is the increased production of reactive oxygen species, which are chemically reactive molecules containing oxygen, as a response to the apneic/hypoxic state described in OSAHS [8]. Such a condition can also contribute to a pro-inflammatory state leading to endothelial dysfunction and damage [9].

Untreated OSA has increased risk for several adverse clinical outcomes. Short-term consequences include excessive daytime sleepiness and impaired daytime function that can cause motor vehicle crashes. It can also be related to potential long-term adverse outcomes, such as metabolic dysfunction, type 2 diabetes, nonalcoholic fatty liver disease, and an increased risk of cardiovascular disease and mortality [10,11].

CPAP Therapy

Continuous positive airway pressure (CPAP) is a type of positive airway pressure where the airflow is introduced into the airways to maintain a continuous pressure to constantly stent the airways open in people who are breathing spontaneously. Positive end-expiratory pressure (PEEP) stands for the pressure in the alveoli above atmospheric pressure at the end of expiration. CPAP is a way of delivering PEEP but also maintains the set pressure throughout the respiratory cycle, during both inspiration and expiration.

CPAP therapy utilizes machines specifically designed to deliver a flow of constant pressure. Components of a CPAP machine include an interface for delivering CPAP. It can be administered in several ways based on the mask interface [1]. Available types of masks include nasal, nasal pillows, oronasal, and oral masks. Nasal masks cover only the nose and must surround it so as not to compress the nasal alae, sitting just above the upper lip and near the angle of the eye. Nasal pillows consist of two nasal inserts and have emerged as an alternative to nasal masks because they are smaller and have less contact with the face. Oronasal masks cover the nose and the mouth and are considered an option for OSA patients with complaints of nasal obstruction and mouth breathing. Oral masks are made of silicone and resemble a butterfly sitting between the lips and teeth. It includes a guide designed to hold the tongue in place and prevent it from blocking airflow from the CPAP [2]. A CPAP machine includes straps to position the mask, a tube that connects the mask to the machine's motor, a motor that blows air into the tube, and an air filter to purify the air entering the nose [1].

A review of the literature evaluating the efficacy of CPAP treatment demonstrated the positive impact of CPAP on the apnea-hypopnea index, sleep architecture, daytime sleepiness, quality of life, neurobehavioral performance, psychological effects, and cardiovascular morbidity [3]. CPAP also improves objective sleep parameters, increasing NREM (Non-rapid eye movement) III or deep sleep stage and reducing snoring [4]. Physiological benefits of CPAP include a greater end-expiratory lung volume and consequent increase in oxygen stores, improving upper airway patency, lower cardiac afterload, and consequent increase in cardiac output. It can also improve pulmonary hypertension and lower blood pressure [5].

Long-Term Benefits CPAP Therapy

Health Outcomes

A study evaluated the long-term effect of CPAP therapy on weight loss outcomes by looking at the change in anthropometric parameters at the follow-up visit. "A significant decrease in BMI in patients using CPAP therapy compared to patients in the non-CPAP group was observed ($p = 0.006$), with a large effect size ($\eta 2 = 0.218$). There was an average loss in BMI of 1.4 ± 3.5 kg/m2 in patients from the CPAP group, compared to an average gain of 1.6 ± 2.5 kg/m2 among the patients not using CPAP therapy" [12-17].

CPAP, the primary treatment for obstructive sleep apnea (OSA), has been shown to normalize the sleep cycle, reduce daytime sleepiness, improve daily function and mood, reduce motor vehicle accidents, and decrease blood pressure and other cardiovascular events. Despite the efficacy of CPAP in reversing sleep apnea, of those studies using the cut point of at least 4 hours per night to define adherence, 29 to 83% of patients were nonadherent [18].

Sleep Quality and CPAP

Loredo et al. found that CPAP significantly enhanced sleep quality in subjects with OSA by consolidating sleep, reducing stage 1 sleep, and improving rapid eye movement sleep. This finding underscores the potential of CPAP therapy to treat OSA and enhance the overall sleep experience, instilling a sense of hope and optimism in both patients [19].

Blood Pressure and CPAP

CPAP treatment is known to reduce the risk of fatal and nonfatal cardiovascular events, which severe OSA significantly increases. In a previous report, it was found increasing evidence of greater cardiovascular risk for untreated mild OSA and improving CPAP acceptance by subjects with mild OSA may be clinically important [20]. However, the important issue is just how much CPAP use is enough to reduce blood pressure. Until recently, 3 meta-analyses focused on the duration of CPAP use, and they

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found that both diurnal SBP and DBP were significantly reduced only with CPAP use for ≥4 weeks and for ≥4 h/night [21].

Quality of Life

Quality of life is an increasingly important consideration in evaluating the benefits of treatment for many conditions. With respect to OSA, QoL has been selected as a quality metric to evaluate the standard of care rendered to patients. Research suggests that QoL among patients with OSA is not only limited to daytime sleepiness, but rather encompasses a wider perception of performance in domains such as physical function, emotional state, and social interaction. This understanding can encourage and motivate both patients and healthcare professionals to prioritize and optimize CPAP therapy [22]. "The current preferred treatment for sleep apnea-hypopnea syndrome (SAHS) is continuous positive airway pressure (CPAP) [23]. Good randomized placebo-controlled evidence shows that CPAP improves SAHS symptoms (especially sleepiness), mood, cognitive function, and quality of life. There is also randomized controlled evidence that patients with sleep apnea-hypopnea syndrome (SAHS) treated with continuous positive airway pressure (CPAP) have improved daytime function and quality of life [23].

Challenges and Adherence

Sleep apnea-hypopnea syndrome (SAHS) is managed using the gold standard therapy of continuous positive airway pressure (CPAP). Despite many advances in machine dynamics for CPAP therapy, such as quieter pumps and softer masks, the adherence rate of CPAP therapy ranges between 30-60% [24]. Numerous factors, such as claustrophobia, cost, comfort, and convenience, are the reasons for such low adherence rates. It is also recognized that many patients who begin down the path of non-adherence often remain non-compliant and eventually discontinue using the machine entirely, leading to the recurrence of symptoms and obstructive sleep apnea (OSA) related adverse effects. Noise, although minimized in newer devices, still poses a disturbance for some patients and their bed partners. Skin irritation and pressure sores from the mask can further discourage use [25].

Furthermore, psychological resistance-such as feelings of stigma, frustration with the treatment, and anxiety about becoming dependent on the device-significantly impacts adherence [26]. To overcome these challenges, interventions like educating patients on the importance of CPAP therapy, employing behavioral therapies to encourage consistent use, and introducing technological innovations such as quieter devices and personalized masks have proven effective in boosting adherence. Implementing these strategies can lead to better patient outcomes by promoting regular CPAP therapy use, thereby reducing the long-term health risks associated with SAHS and reducing the risk of cardiovascular event recurrence [27].

Technological Advances

In recent years, the management of Sleep Apnea-Hypopnea Syndrome (SAHS) through Continuous Positive Airway Pressure (CPAP) therapy has significantly evolved, with technological advancements enhancing both the efficacy and user experience of the treatment. These innovations are pivotal in addressing long-term adherence challenges and optimizing therapeutic outcomes.

Smart CPAP Devices

One of the most notable advancements in CPAP technology is the development of smart CPAP devices. These machines are equipped with auto-adjusting features that automatically modify the pressure levels based on the patient's needs throughout the night. This capability ensures that the pressure is optimized for the individual's specific condition, reducing discomfort and improving adherence to therapy [18].

Additionally, modern CPAP devices often come with integrated humidifiers, which maintain airflow moisture levels, preventing airways' dryness and irritation. This feature is particularly beneficial for patients who experience nasal congestion or throat irritation, as it enhances comfort and supports consistent use [12]. Moreover, smart CPAP devices now include connectivity features that allow for remote monitoring. Through wireless technology, data from the CPAP machine can be transmitted to healthcare providers, enabling real-time monitoring of the patient's adherence and therapeutic outcomes. This connectivity facilitates timely interventions and adjustments to the treatment plan, ultimately improving the overall management of SAHS [28].

Improved Mask Designs

Comfort and fit are critical factors in CPAP therapy adherence, and recent innovations in mask designs have significantly contributed to improvements in these areas. Manufacturers have developed masks that are lighter, more flexible, and designed to minimize pressure points on the face. These improvements help reduce skin irritation and discomfort, which are common complaints among CPAP users [29]. Innovative mask designs also aim to reduce air leaks, a common issue that can disrupt therapy and diminish its effectiveness. Newer masks use advanced sealing technologies and customizable fit options, allowing users to find a mask that suits their facial structure more accurately. This customization not only enhances comfort but also ensures that the therapeutic pressure is maintained throughout the night, thereby improving the efficacy of the treatment [13].

Data Integration

The integration of data-tracking capabilities into CPAP devices represents a significant leap forward in the personalization of SAHS management. Modern CPAP machines have sensors that

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can monitor and record various health metrics, including usage hours, mask fit, and even events related to apneas and hypopneas. This data is invaluable for both patients and healthcare providers, as it allows for the detailed analysis of treatment efficacy [28]. Furthermore, the collected data can be used to create personalized treatment plans that cater to the patient's specific needs. For instance, healthcare providers can adjust pressure settings, recommend mask type changes, or address comfort-related issues based on the insights gained from the usage data. This approach ensures that the treatment is continuously optimized, improving long-term outcomes for SAHS patients [18]. In conclusion, the technological advancements in CPAP therapy-ranging from smart devices and improved mask designs to sophisticated data integration-have revolutionized the management of Sleep Apnea-Hypopnea Syndrome. These innovations not only enhance the effectiveness of the therapy but also address many of the challenges related to long-term adherence, paving the way for better patient outcomes.

Patient Perspectives

Patient Experience

Patient perspectives on long-term Continuous Positive Airway Pressure (CPAP) therapy often reveal a blend of benefits and challenges. According to recent studies, many patients appreciate the improved sleep quality, mental health, and reduced daytime sleepiness from CPAP. For instance, a study by Moon, Y. K., Lee, J., & Choi, H. on patients with an apnea-hypopnea index (AHI) ≥15 were included (n=579). Also, "patients with national health insurance (NHI) were more adherent, benefited from CPAP therapy, tolerated PAP had a higher AHI, longer duration of oxygen desaturation (<90%), and less dream enactment behavior (DEB) than that in those who did not" [30]. These findings underscore the need for health insurance for personalized solutions and continuous support to improve the CPAP experience and adherence.

In a qualitative study by Shapiro et al., with an initial 66 participants with 1-month adherence, 33 in 3-year follow-up patients expressed frustration with the mask fit and noise, which sometimes led to discontinuation of therapy [31]. One participant noted, "The mask feels too bulky and makes it hard to sleep comfortably" [32]. "Life satisfaction was significantly higher at present compared with before wearing CPAP ($t = 5.17$, $p < .001$)" [33]. However, long-term adherence to CPAP therapy can be hindered by discomfort and inconvenience.

A systematic review by Patil et al. highlighted how "sleep-related quality of life (QOL) in patients with sleep problems can be impaired by related symptoms, such as sleep, morning headaches, nocturia, impairments in productivity or social functioning, and daytime fatigue" [32]. The strength of the study was "the inclusion and synthesis of evidence not only from RCTs, which provided a high level of evidence but also from well-conducted propensity score-adjusted observational studies, which can provide valuable complementary evidence" [32].

Balk et al. studies with 38 eligible studies compared CPAP prescription, use, or adherence with no (or rarely, sham) CPAP prescription, use, or adherence. The authors utilized 16 RCTs, including 7,664 participants, and 22 nonrandomized comparative studies with multivariable adjustments for outcomes of interest, including 268,033 participants. This combined analysis of RCT and high-quality observational data adds robustness and comprehensiveness to their findings [34]. Again, irrespective of the discrepancies between results studies on the effect of CPAP on all-cause mortality, this critical systematic review demonstrated crucial gaps in the evidence around the long-term effects of CPAP for OSA, and CPAP being a standard treatment" [34]. The authors show "a lack of high-quality data from randomized trials demonstrating benefits of CPAP therapy on critical health outcomes like mortality and cardiovascular events, such as stroke, myocardial infarction, and atrial fibrillation" [34]. These findings factor in the need for further studies, especially RCTs, to comprehensively understand the effects of CPAP therapy on health outcomes and to establish treatment strategies for the long-term benefit of patients.

Impact on Daily Life

Patients undergoing Continuous Positive Airway Pressure (CPAP) therapy for obstructive sleep apnea report significant changes in their daily lives, relationships, and overall lifestyle. Research highlights both positive and negative impacts. On the positive side, CPAP therapy can significantly improve in home settings, hospitals, and laboratories by improving sleep quality, daytime alertness, neurocognitive performance, and mood and enhancing overall daily life engagement productivity [35]. Home setting benefits for long–term use of CPAP include lower cost effectiveness, home comfort/love, increased interest in using treatment, and greater access to care. According to Brown et al., CPAP therapy's impact extends to mental health as well, with many patients reporting decreased anxiety and depressive symptoms following successful treatment [33]. Patil et al. identified the "cruciality of continuous PAP (CPAP), auto-adjusting PAP (APAP), bi-level PAP (BPAP), and other advanced PAP modalities for central sleep apnea and hypoventilation as frameworks" [32].

Irrespective of the potential effectiveness of CPAP therapy, there are challenges which not only include non-adherence to device use, poor literacy level of patient/caregiver, inability to identify/rectify or troubleshoot equipment problems related to mask fit, leak, or other PAP-related issues at night of use. Patients on CPAP may also encounter social-relationship issues due to moving about with PAP, noise at night time, routine interference, and discomfort of wearing a CPAP mask [32]. Above all, while CPAP therapy effectively manages sleep apnea and improves health outcomes, it comes with adjustments that impact daily life and interpersonal relationships [36,37].

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Future Directions

Emerging Treatments

Patients often choose alternative therapies to CPAP due to discomfort, difficulty, and inconvenience, despite its effectiveness [38]. High-pressure settings can disrupt sleep, and CPAP masks may cause discomfort, skin irritation, and claustrophobia, leading many to seek more manageable options like oral appliances, which are less cumbersome [37]. Mandibular Advancement Devices (MADs) hold the jaw forward to increase the pharyngeal area and prevent airway blockage, making them suitable for mild to moderate OSA. However, MADs may cause dental, periodontal, and temporomandibular joint issues due to prolonged use, and success rates may be lower for those with pre-existing dental issues. MADs can significantly reduce symptoms and improve sleep quality, though they may be less effective in severe cases or with limited mandibular protrusion [36]. Tongue Retaining Devices (TRDs) use suction to hold the tongue forward, preventing airway obstruction. TRDs were effective in 71% of cases and improved daytime symptoms comparably to MADs [39]. Daily compliance with TRDs (79%) is close to that of MAD users (92%) [40]. Discomfort is a common reason for discontinuation of both TRDs and MADs. Hypoglossal Nerve Stimulator Therapy (HGNS) is used for moderate to severe OSA when CPAP is intolerable; it stimulates the hypoglossal nerve to induce tongue stiffening and protrusion [41]. Transoral Awake State Neuromuscular Electrical Stimulation (NMES) Therapy strengthens tongue muscles to reduce airway obstruction in mild OSA and is well-tolerated and accepted by patients due to its daytime application [42,43].

Surgical and Bariatric Interventions

Surgery for OSA aims to improve airflow by removing or repositioning obstructive tissues, typically when CPAP or oral appliances are ineffective or intolerable. Nasal reconstruction corrects structural issues like a deviated septum. Uvulopalatopharyngoplasty (UPPP) removes excess tissue from the soft palate and pharynx to widen the airway. Uvulopalatopharyngoglossoplasty combines UPPP with limited tongue base resection to further enlarge the airway. Genioglossus advancement (GA) repositions the genioglossus muscle to prevent airway collapse, while maxillomandibular advancement (MMA) repositions the upper and lower jaws to enlarge the airway. Adenotonsillectomy is commonly performed in children but often does not lead to complete resolution [44,45]. Tracheostomy is considered only in urgent cases or when other treatments fail or are refused [46]. Bariatric surgery is a viable option for obese individuals with OSA, improving both obesity-related OSA and overall sleep quality [45].

Pharmacological Treatments

Various pharmacological treatments, such as modafinil and armodafinil, are available to treat residual daytime sleepiness in patients who still experience sleepiness despite receiving effective CPAP treatment [47]. Antihypertensive medications, including MRAs and ACEIs/ARBs, manage OSA-related hypertension and can reduce the condition's severity [48]. Acetazolamide may aid patients with central sleep apnea by stimulating breathing through mild metabolic acidosis, showing short-term improvements in both OSA and CSA. Further rigorous, long-term studies are needed to determine acetazolamide's chronic treatment value for sleep apnea [49].

Research Gaps

CPAP adherence is affected by factors such as age, gender, race, socioeconomic status, smoking, OSA severity, symptom intensity, psychological factors, social support, and common issues like dry nose and mask leaks. Positive early experiences and a supportive environment are crucial for long-term adherence. Therefore, patient education and tailored behavioral strategies are essential for improving adherence and treatment outcomes. Further research is needed to develop cost-effective interventions for patient care [50]. Additionally, the long-term impact of untreated mild Sleep Apnea Hypopnea Obstructive Syndrome (SAHOS) requires more study, as untreated cases can lead to serious health issues like hypertension and heart disease [50].

Conclusion

Obstructive Sleep Apnea-Hypopnea Syndrome (OSAHS) presents a complex and multifaceted challenge with significant health implications. Continuous Positive Airway Pressure (CPAP) therapy remains the gold standard in managing OSAHS, demonstrating substantial benefits in improving sleep quality, reducing daytime sleepiness, and lowering cardiovascular risks. However, issues with adherence persist, influenced by a range of factors, including device discomfort and psychological resistance. Technological advancements, such as smart CPAP devices, improved mask designs, and data integration, have significantly enhanced CPAP therapy's effectiveness and user experience. Despite these improvements, there remains a critical need for ongoing research to address adherence challenges, explore alternative treatments, and evaluate the long-term impact of untreated mild OSAHS. Enhanced patient education and tailored support strategies are essential to optimizing treatment outcomes and mitigating the health risks associated with OSAHS.

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How to cite this article: Vianka Vanessa YM, Melanie Dayana YM, Lilian RDR, Chinyere P, Yolanda Maria FM, et al. Long-Term Management of Sleep Apnea-Hypopnea Syndrome: Efficacy and Challenges of Continuous Positive Airway Pressure Therapy. Int J Pul & Res Sci. 2024; 7(3): 555713.
DOI: 10.19080/IJOPRS.2024.07.555713

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