When to Treat with CPAP and How to Define Success

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Abbreviations

AF	Atrial fibrillation
AHI	Apnea-hypopnea index
APAP	Auto-adjusting continuous positive airway pressure
ASV	Adaptive servo ventilation
BP	Blood pressure
BPAP	Bi-level positive airway pressure
CAD	Coronary artery disease
CHF	Congestive heart failure
CMS	Centers for Medicare and Medicaid Services
CPAP	Continuous positive airway pressure
CVD	Cardiovascular disease
ESS	Epworth Sleepiness Scale
FOSQ	Functional Outcomes of Sleep Questionnaire
LVEF	Left ventricular ejection fraction
OSA	Obstructive sleep apnea
QoL	Quality of life
SAQLI	Sleep Apnea Quality of Life Index
SF36	Medical Outcomes Study Short-Form Health Survey

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1.1 Historical Perspective and Description of Methods of Positive Airway Pressure Delivery

1.1.1 Evolution of Positive Airway Pressure

The concept of administering continuous positive airway pressure (CPAP) for treatment of lung injury began in the 1970s. However, it was not until 1980 that Colin Sullivan, an Australian physician and professor, proposed using nasal continuous positive airway pressure (CPAP) as a means to treat obstructive sleep apnea (OSA) [1]. Up until the discovery of CPAP, tracheostomy was the recommended treatment modality for severe cases of OSA [2]. The first commercially available CPAP devices in North America were manufactured in 1985. Since then, there have been improvements made to the original CPAP device, and more specialized models have been developed for alternative methods of delivery of positive airway pressure (PAP). Over the past 35 years, CPAP has become the *gold standard* and most commonly prescribed treatment for OSA worldwide.

1.1.2 Description of Various PAP Modes

Since the introduction of CPAP as a treatment for OSA, a number of refinements have been made to the method by which PAP is delivered to the patient. In general, these PAP modes were developed in response to the inability of simple CPAP to successfully treat some patients with OSA. In order to comprehend what constitutes treatment success with CPAP, it is important to understand these modes of PAP delivery as well.

1.1.2.1 Continuous and Auto-Adjusting Positive Airway Pressure (CPAP and APAP)

Continuous positive airway pressure as the name suggests delivers a relatively constant positive airway pressure during both inspiration and expiration. Auto-adjusting CPAP or

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APAP functions like CPAP, but in addition, it automatically titrates the delivered pressure in response to detected upper airway narrowing or closure during episodes of apnea or hypopnea. With APAP, CPAP pressures are adjusted by using changes in airflow and vibration from sensors in the airway circuit. The algorithms are proprietary, and manufacturers' devices perform differently in simulation studies [3] suggesting that functional differences could occur in patients as well.

1.1.2.2 Bi-Level PAP (BPAP) and Auto-Adjusting BPAP

Bi-level PAP delivers higher pressures during inspiration and lower pressures during expiration. Specialized models offer a spontaneous timed (ST) mode with an option to specify a backup respiratory rate in the absence of inspiratory effort. Auto-adjusting BPAP devices automatically adjust expiratory pressures in response to detected apneas and adjust inspiratory pressures in response to hypopneas and respiratory flow limitations. BPAP is generally used for patients who either cannot tolerate or fail to be adequately treated with CPAP with mixed success [4].

1.1.2.3 Adaptive Servo Ventilation (ASV)

Adaptive servo ventilation, like BPAP, delivers higher inspiratory and lower expiratory pressures. Additionally, it varies the inspiratory pressure support on a breath-by-breath basis, within prespecified limits to achieve a target ventilatory flow. It can be set in either a fixed or variable mode with respect to delivery of expiratory pressures and backup respiratory rates. The most frequent use of ASV is for treatment of central or treatment-emergent central sleep apnea [5].

1.2 When to Treat with CPAP

The most common use of CPAP is for treatment of either symptomatic OSA or asymptomatic OSA in the setting of significant comorbid medical conditions. Additionally, CPAP is sometimes used in certain types of central sleep apnea [6].

1.2.1 Obstructive Sleep Apnea (OSA)

Obstructive sleep apnea is characterized by repetitive upper airway collapse or near collapse. The severity of OSA is defined by the apnea-hypopnea index (AHI). An AHI <5/hour is considered absent or minimal OSA. Mild OSA is defined as an AHI ≥5/hour and <15/hour. Moderate is defined as ≥15 and <30/hour and severe is ≥30/hour.

1.2.1.1 Treatment of Symptomatic OSA

The most common indication for the use of CPAP is to treat symptoms associated with OSA, and it remains the gold standard for therapy [7]. In the absence of complications, CPAP or APAP adequately treats the majority of patients. The following are commonly reported symptoms and their responsiveness to CPAP.

Excessive Daytime Sleepiness

Excessive daytime sleepiness is one of the cardinal symptoms of OSA and is present in up to half of patients [8]. It is generally a subjective complaint, but multiple clinical tools (see Sect. 1.3.2.1) are available for use in an attempt to achieve some uniformity in definition. The most widely used clinical questionnaire is the Epworth Sleepiness Scale (ESS). A score of >10 on ESS is consistent with excessive sleepiness. Either by self-report or by use of the ESS, CPAP has been shown to improve sleepiness after treatment in majority of sleepy patients with OSA [8].

Sleep Quality

Sleep disturbances/poor sleep quality is another common feature of the OSA with patients reporting insomnia symptoms such as difficulty falling and staying asleep and non-restorative sleep. The former may be confirmed on polysomnography. Polysomnographic electroencephalographic tracings may also suggest paradoxical insomnia, where, despite having slept during the study, the patient reports a sensation of not having slept at all likely due to the overall poor quality of sleep. Sleep quality has been shown to improve with CPAP in patients with moderate to severe OSA and comorbid insomnia, some of whom were deemed to have treatment-resistant insomnia prior to treatment of OSA. Improvements have been demonstrated using both self-reported symptoms measured via tools such as the Insomnia Severity Index and sleep quality scales (see Sect. 1.3.2.1) and objective polysomnographic findings of reduced sleep onset latency, reduced wake after sleep onset, increases in sleep efficiency, and improved sleep architecture on CPAP [9].

Snoring/Apneas

As a general rule, CPAP is not recommended for primary snoring, but when used for treatment of OSA, there is an added benefit of partial or complete resolution of snoring [10]. Apneic episodes are also observed to decrease or resolve either by apnea-sensitive patients or their bed partners with the use of CPAP. These changes have been documented objectively via reductions in the apnea-hypopnea index (AHI) either via polysomnographic monitoring or download of CPAP data [11].

Cognitive Issues

The relationship between OSA and cognition is complex, with considerable variation in reported symptoms. Common examples include difficulty concentrating, difficulty learning new material, and memory impairment (for more detail, see Sect. 1.3.2). Reports of subjective improvement in these symptoms with CPAP use are variable. Some studies have reported partial improvement in cognitive symptoms with CPAP use in severe OSA patients only [12], and others report only mild and transient improvements [13]. The consistent use of CPAP has been shown to confer some benefit in patients with mild cognitive impairment by improving cognition in some cases while slowing the rate of cognitive decline in others [14]. Thus, CPAP is sometimes initiated in patients with OSA and cognitive impairment with a primary goal to reverse or slow decline.

Mood

There is considerable overlap between symptoms of untreated OSA and depression, and many cases of OSA are misdiagnosed as depression (also see Sect. 1.3.6). Insomnia, lethargy, and psychomotor retardation can occur in either condition. CPAP has been associated with subjective improvement in mood [15], particularly those overlapping symptoms described above, and increased use of CPAP has been associated with faster rates of improvement in those same domains on the Hamilton Depression Scale [16]. Improvements in other depression scales like the Patient Health Questionnaire 9 scores have also been documented with CPAP use [17].

Overall Quality of Life (QoL)

Patients with untreated OSA often report poor quality of life mainly described as impairment in daytime function. Therefore, one of the primary indications to treat with CPAP in OSA patients is to improve their quality of life. Following treatment with CPAP, and in the absence of other comorbidities impairing daytime function, patients often report improvement in symptoms related to their quality of life. Objective data using sleep-related quality of life measurement tools such as the Calgary Sleep Apnea QoL Index (SAQLI) have shown significant improvement following the treatment of severe OSA with CPAP, but less so with mild to moderate OSA [18]. Similar improvements were demonstrated on the FOSQ-10 and the Quality of Life Enjoyment and Satisfaction questionnaires in a cohort of patients with OSA and insomnia [9]. Improvement after CPAP using general quality of life instruments has been reported but is less consistent. For example, a study in women with moderate to severe OSA documented improvement in QoL indices with CPAP use on the Quebec Sleep Questionnaire [19]. However, there was no improvement with CPAP using the Quality of Well-Being Self-Administered Questionnaire [20].

1.2.1.2 Prevent or Treat Comorbid Medical Problems

The pathophysiology of OSA strongly suggests that it is a pro-inflammatory condition. Chronic inflammation is a common underlying condition in several chronic medical diseases including cardiovascular disease. The associated chronic intermittent hypoxia and repeated arousals, which are consequences of OSA, are the underlying reason for the cascade of events which result in inflammation. Use of CPAP in OSA patients may be useful in the prevention and treatment of these conditions.

Cardiovascular Disease (CVD)

Sleep-disordered breathing has long been associated with increased cardiovascular risk in new [21] and established patients with CVD [22]. The prevalence of OSA in patients with cardiovascular disease is up to 60% [23]; see Sect. 1.3.3. OSA is associated with an increased atherosclerotic burden courtesy of systemic inflammation, which is a consequence of oxidative stress and sympathetic activation. It has been found to be an independent risk factor for atherosclerosis. Treatment of OSA has been shown to significantly improve early signs of atherosclerosis [24]. In a randomized controlled trial conducted on a cohort of patients with moderate to severe OSA, CPAP was found to improve myocardial perfusion reserve on multiple modalities of cardiovascular imaging when compared to the sham CPAP group. These findings suggest that treatment of OSA may lessen endothelial dysfunction and hence prevent the development of overt cardiovascular disease [25].

Coronary Artery Disease

Cohort studies show a clear association of incident coronary artery disease (CAD) in severe OSA [26]; also see Sect. 1.3.3. In populations with cardiovascular disease, OSA predicts subsequent major cardiovascular events [22]. Some studies indicate that the treatment of OSA with CPAP in CAD patients is associated with a decrease in the occurrence of new cardiovascular events and an increase in the time to such events [27], while some report a significant reduction in subsequent major cardiovascular events in CAD patients compared with those left untreated [28]. However, in other studies, interventions using CPAP to reduce incident or recurrent CAD have failed to provide confirmatory data. These studies have been controversial, possibly due to the heterogeneity of study populations and poor adherence to CPAP [29]. Nevertheless, the presence of CAD in those with moderate to severe OSA is an indication for treatment with CPAP even in the absence of clinical symptoms. The case for treatment in those with mild OSA is less compelling.

Atrial Fibrillation (AF) and Other Arrhythmias

Acutely, OSA causes negative intrathoracic pressure, intermittent hypoxia, and sympathetic activity which predispose to arrhythmias. Hypoxia also increases vagal tone and promotes bradycardia and heart conduction abnormalities. In the long term, OSA may cause remodelling of the heart and promote arrhythmogenicity [30]. Up to 48% of patients with OSA have been found to have arrhythmias and heart conduction abnormalities during sleep [31]. Bradycardia, heart block, non-sustained ventricular tachycardia, atrial fibrillation, and sudden cardiac death have been described in OSA. AF appears to be the most commonly described, however.

OSA is an independent risk factor for incident AF and is directly related to the severity of OSA [32]. Nocturnal palpitations can be a presenting symptom of atrial fibrillation associated with OSA. When OSA is comorbid with AF, patients have worse symptoms and higher risks of hospitalization than patients without OSA, although disease progression and outcomes are similar in both groups [33]. Furthermore, patients with untreated OSA have a higher recurrence of AF after cardioversion than patients without. Adequate treatment of OSA with CPAP has been associated with lower recurrence of AF after cardioversion or ablation [34]. However, most of the findings are from observational studies and are not always reproducible [35]. Further recent information is provided in Sect. 1.3.3.

Bradyarrhythmias including nocturnal heart block are sometimes found in OSA. One study found more than half of patients with implanted pacemakers for bradyarrhythmias had OSA defined as AHI of ≥10 events per hour of sleep [36]. Treatment of OSA with CPAP can prevent the need for a pacemaker in patients with exclusively OSA-related bradyarrhythmias which tend to occur following episodes of severe oxygen desaturation. Clear improvements in bradyarrhythmias have been demonstrated on overnight Holter monitors with CPAP [37].

Data linking OSA to the pathogenesis of cardiac arrhythmias, particularly AF, are compelling. Thus, evaluation for OSA and treatment with CPAP in the setting of new-onset or worsening arrhythmias should be performed.

Stroke

OSA is an independent risk factor for ischemic stroke through a similar pathway that predisposes to cardiovascular disease in general. Another indirect pathway is via the increased risk of AF in OSA patients which can contribute to cardioembolic strokes. However, it has been postulated that these vascular events may also occur in OSA patients through mechanisms independent of AF [38].

OSA is highly prevalent in stroke patients [39], and stroke risk increases with greater severity of OSA. Severe obstructive sleep apnea (OSA) increases the risk for incident stroke and recurrence of stroke and worsens stroke outcomes. Continuous positive airway pressure may reduce stroke risk and improve functional outcomes, particularly in treatment-compliant patients [40].

Hypertension

There is an increased prevalence of systemic hypertension in OSA, and untreated OSA contributes to resistant hypertension. The importance of OSA in the pathogenesis of hypertension was highlighted in the 7th Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure [41].

The severity of OSA correlates with the severity of hypertension [42]. These findings are attributed to oxidative stress and consequent endothelial dysfunction. Nocturnal non-dipping of blood pressure (BP) during sleep has been noted in OSA patients.

Use of CPAP with adequate compliance has been shown to improve blood pressure readings particularly in moderate and severe OSA patients with resistant hypertension [43]. There appears to be a strong linear dose response between duration of CPAP use and reductions in BP [44], although some studies have reported only mild BP changes [45]. Evaluation for OSA and treatment with CPAP are indicated for hypertensive patients with a history suggestive of OSA or poorly controlled hypertension.

Congestive Heart Failure (CHF)

Severe OSA has been associated with increased incidence of congestive heart failure [26]. This may be related to the degree of hypoxia associated with OSA as demonstrated by a study done on a cohort of men with OSA [46]. Use of CPAP has been shown to be helpful in CHF patients with comorbid OSA as shown by improvements in left ventricular ejection fraction (LVEF) in patients with milder degrees of systolic dysfunction (LVEF >30%) [47]. The benefits of CPAP therapy in hospitalized OSA patients with acute exacerbation of CHF have been controversial with some studies documenting reduced readmission rates for CHF [48] and others reporting no reductions in length of stay or readmission rates [49]. Nevertheless, potential benefits of treating CHF patients who have been identified as having OSA with CPAP outweigh any risks.

Type 2 Diabetes Mellitus

Obstructive sleep apnea is associated with alterations in carbohydrate metabolism, impaired glucose tolerance, and insulin resistance, and this has been found to be independent of obesity [50]. The systemic inflammatory response associated with OSA also affects appetite-regulating hormones as well as the hypothalamic-pituitary-adrenal axis. These factors

suggest that OSA may be an independent risk factor for type 2 diabetes mellitus. The prevalence of OSA among individuals with type 2 diabetes mellitus is extremely high approaching 85% in one study [51]. Although the effect of treatment with CPAP in those with type 2 diabetes and OSA is conflicting, patients with type 2 diabetes mellitus should be screened for OSA and provided a trial of CPAP if OSA is present [52].

Other Medical Conditions

The presence of OSA has been implicated in the pathogenesis of several other medical conditions. For individual patients, CPAP may be indicated as adjunctive treatment.

Chronic Kidney Disease (CKD)

Obstructive sleep apnea is moderately prevalent in chronic kidney disease. It may accelerate loss of kidney function due to oxidative stress leading to endothelial dysfunction and atherosclerosis. Furthermore, OSA worsens hypertension by activating the renin-angiotensin-aldosterone axis, contributing to a decline in kidney function [53]. It has also been associated with higher risk of incident end-stage renal disease [54]. Comorbid OSA is regarded as deleterious in kidney transplant patients. Screening and management is recommended in this population [55]. In one study, CPAP has been shown to slow the progression of CKD in patients with moderate and severe OSA [56].

Non-alcoholic Fatty Liver Disease

Non-alcoholic fatty liver disease is a disorder of altered carbohydrate metabolism, which also is one of the hallmarks of OSA. This appears to be a consequence of chronic intermittent hypoxia [57]. Untreated OSA patients have been found to have increased levels of serum markers as well as cellular evidence of liver damage. However, the role of CPAP in mitigating this risk has not been confirmed.

Gastroesophageal Reflux Disease (GERD)

Gastroesophageal reflux disease has been found to be prevalent in OSA patients, and this is independent of common risk factors like obesity, age, or gender. A causal relationship has been proposed due to observation of lower esophageal relaxation in OSA. CPAP has been found to improve GERD symptoms [58].

Chronic Headaches

Morning headaches can be a presenting symptom of OSA. The underlying reason for this may be multifactorial. Potential factors include hypoxia, sleep disruption, poor sleep quality, and co-existing hypercapnia which may be observed in complicated OSA phenotypes. Patients with morning headaches should be evaluated for OSA as the use of CPAP may be beneficial in some patients [59].

Pulmonary Hypertension

Chronic intermittent hypoxia, which results from OSA, leads to pulmonary arterial vasoconstriction and pulmonary hypertension. The degree of hypoxia is more contributory to the altered dynamics in the pulmonary vasculature rather than the frequency of sleep-disordered breathing events. Nevertheless, treatment of OSA with CPAP may reduce the severity of pulmonary hypertension [60].

1.2.1.3 OSA Severity and Decision to Use CPAP

Moderate and severe OSA are established indications for treatment with CPAP to prevent well-documented acute and chronic medical complications even in the absence of clinical symptoms. However, because the impact of mild OSA on associated medical conditions is not well established, the decision to treat is largely dependent on the presence of relevant symptoms like excessive daytime sleepiness and insomnia and associated cardiovascular comorbidities or mood disorders [61].

1.2.2 Central Sleep Apnea

1.2.2.1 Closed Airway Central Sleep Apnea

Central events may occur with pharyngeal narrowing or occlusion [62]. A more compliant airway and ventilatory controller instability are predisposing factors [6]. The consequent hypoxia during these events results in compensatory hyperventilation, and the ensuing hypocapnia further drives respiratory instability and central apneas. The use of CPAP by preserving upper airway patency during central events can help reduce hypoxia and stabilize breathing [62] and be an effective treatment in those who appear to have only central sleep apnea.

1.2.2.2 Treatment-Emergent Central Sleep Apnea

The emergence of new-onset central respiratory events during sleep when a patient is started on CPAP therapy is common and has been observed in up to 6.5% of patients treated with PAP therapy. Such de novo central events (also referred to as complex sleep apnea) are thought to be transitory, and the majority will resolve within 8 weeks [63]. Persistent cases warrant a switch to an alternative mode of PAP therapy where appropriate such as ASV. Underlying risk factors for central sleep apnea should also be identified and addressed.

1.3 Defining Treatment Success

There are two general methods used to assess treatment success with PAP therapy. The first is self-report of whether there is resolution of OSA symptoms. This includes various

questionnaires such as the ESS and a number of QoL tools. The second is objective determinations of CPAP adherence. Both methods should be used to ascertain treatment success.

1.3.1 Self-Report

Improvement or resolution of symptoms can only be assessed by querying the patient. At a minimum, patients should be asked about daytime sleepiness, napping, snoring, and quality of their sleep. It is especially important to inquire about episodes of inattention or frank sleepiness while driving. Documentation of the patient's bedtime, sleep latency, episodes of wake after sleep onset, and wake time may also be useful. These can then be compared to answers before starting CPAP. If available, it can be helpful to ask the same questions to a bed partner in order to corroborate the patient's answers. In some cases, patients may wish to downplay the severity of their symptoms; the bed partner's viewpoint can be a more accurate appraisal of the situation.

Complete resolution of symptoms is the best outcome. However, many patients will report improvement, but still have residual symptoms. In addition, for some patients, there unfortunately will be little or no improvement despite objective evidence of adequate or even optimum use of CPAP therapy [64]. In such cases, other explanations for lack of improvement should be sought. For example, other sleep issues may still be present such as inadequate amount of time in bed trying to sleep or disruption of sleep continuity from environmental noise. However, in a number of instances, there is persistent hypersomnia despite good CPAP adherence with no other explanation. This has been attributed to a residual effect of long-standing untreated OSA [64].

In addition to an assessment of symptoms, patients should be asked whether they use their PAP device nightly and for how long each night. If they do not use it nightly or they use it for less than their time in bed, the usage frequency and amount of time used should be ascertained. In such cases, patients often overreport their use either because they are poor at estimation or because they wish to appear compliant with therapy at the time of their clinic appointment [65]. Adverse effects from PAP use such as facial rash or sores and noticeable amounts of air leakage around the mask should be elicited.

1.3.2 Questionnaires

Various questionnaires are sometimes used to assess whether PAP treatment is beneficial. The most common instruments assess QoL or daytime sleepiness. Both of these constructs are used as quality measures by the American Academy of Sleep Medicine and are thus intended as a metric of quality of care in the practice of Sleep Medicine [66].

1.3.2.1 Quality of Life Instruments

Results from generic quality of life instruments such as the Medical Outcomes Study Short-Form Health Survey (SF36) can be inconsistent or insensitive to changes in quality of life experienced by those with OSA [67]. Although there have been few studies [68, 69], sleep-specific tools such as the Functional Outcomes of Sleep Questionnaire (FOSQ) and the Sleep Apnea Quality of Life Index (SAQLI) correlate poorly with the SF36 suggesting that they may perform better in patients with sleep apnea-related symptoms. Both are either relatively long or require in-person administration. However, short versions like the FOSQ-10 are now available and may be more useful in a clinical setting. Studies in OSA patients treated with CPAP indicate that the FOSQ and SAQLI reflect changes in QoL after treatment with CPAP [18, 70].

1.3.2.2 Assessment of Daytime Sleepiness

The most common instrument used for assessment of daytime sleepiness is the Epworth Sleepiness Scale. Originally developed by Dr. Murray Johns in 1991 [71], it has been translated and validated in multiple languages. It is a self-administered questionnaire where individuals rate their usual chances of dozing off or falling asleep in eight common situations or activities on a 4-point scale (0–3). Hence, the minimum possible score on the scale is 0 (not sleepy at all), and the maximum is 24 (extremely sleepy). Scores >10 are considered indicative of excessive sleepiness. However, it is only modestly correlated with self-reported assessments as well as with objective measures of sleepiness such as the multiple sleep latency test [72]. Unfortunately, it has been misused by insurance companies, with low scores cited as a rationale for denying approval for diagnostic testing or initiation of treatment [73]. Nevertheless, the ESS has been shown to improve after CPAP use [13].

Two other instruments, the Karolinska Sleepiness Scale and the Stanford Sleepiness Scale, are used less commonly to quantify sleepiness. The Karolinska Sleepiness Scale assesses subjective sleepiness at a particular point in time. It is a 9-point scale with a "1" indicating extreme alertness and a "9" indicating extreme sleepiness [74]. A score of 7 or higher is felt to represent significant sleepiness. The Stanford Sleepiness Scale also rates sleepiness at the time the instrument is completed. It is a 7-point scale with a "1" defined as "Feeling active, vital, alert, or wide awake" and a "7" described as "No longer fighting sleep, sleep onset soon; having dream-like thoughts" [75]. Although commonly used in research settings, normative data are not available. Inasmuch as both the Karolinska Sleepiness Scale and the Stanford Sleepiness Scale convey an assessment of sleepiness

at only a single point in time, they have limited clinical utility. However, they can be administered multiple times during any time period.

1.3.3 Objective Assessment of CPAP Adherence

The limitations inherent in subjective reporting of symptoms and CPAP usage led to the evolution of objective methods of assessing sleepiness and adherence to CPAP therapy. Objective evaluation of sleepiness in the context of CPAP therapy is not usually performed because of the expense of performing studies such as the multiple sleep latency test. However, objective evaluation of CPAP adherence has become a treatment "gold standard." Early generation CPAP devices were able to provide crude determination of device usage by measuring the amount of time the device was "turned on." With the advent of advanced pressure sensors and microprocessors, new devices are now able to record the amount of time the CPAP interface or mask is worn. Initially, such data were saved on a storage card, which could be removed for data download. Currently, they are sent into the "cloud" where they can be accessed by both the patient and clinicians in near real time. Review of adherence data is now considered standard of care by sleep clinicians at the time of follow-up visits by patients with OSA; third-party reimbursement for CPAP may be contingent upon objective documentation of a minimal level of usage [76].

1.3.3.1 Interpretation of PAP Compliance Reports

Reports from CPAP devices contain data in four areas: device usage, set and delivered pressures, AHI measured from the device, and estimates of air leak. However, because CPAP devices do not have oximetry capabilities, data regarding oxygen saturation or desaturation events are not included. Device usage is generally provided as the average amount of time used over a 30-day interval. Additionally, the number and percent of days used and number and percent of nights with 4 or more hours of use are reported. For pressure data, reports specify the PAP mode (e.g., CPAP, APAP, BPAP) and the prescribed settings. For device modes which automatically adjust the therapeutic pressure such as APAP, the most important parameter provided is the 90 or 95 percentile pressure. This is the pressure at which the device spent 90 or 95% of the night at or below. For example, if an individual used the device for 10 hours and 9 hours was spent at or below 10 cm H_2O, then the 90 percentile pressure would be 10 cm H_2O. Some device manufacturers provide the 90 percentile pressure and others the 95 percentile pressure. In addition, the average peak airway pressure is provided. One of the most important metrics provided on a CPAP report is the device-measured AHI. This parameter is derived from changes in airflow measured internally by the device. It is reasonably accurate but tends to slightly overestimate severity at lower AHI values and underestimate at higher values [77]. However, differentiating between obstructive and central events may not be reliable. Finally, estimates of mask leak are provided. Some intentional leakage is inherent with the use of PAP in order to avoid CO_2 rebreathing. However, large amounts of unintentional leakage from around the mask cause facial and eye irritation and may result in poor adherence to therapy [78].

Objective evidence of treatment success is commonly defined as an AHI <5/hour and usage for at least 70% of nights for more than 4 hours per night [76]. Achievement of this goal is adversely affected by the need for high pressures and the presence of excessive amounts of unintentional leak. In a small number of cases, there will be a need to document resolution of oxygen desaturation while on PAP therapy. This will require a continuous nocturnal oximetry recording in addition to the standard PAP usage report.

1.3.3.2 What Is Treatment Success?

Successful treatment with PAP is not an all or none determination despite the large amount of pertinent information available. Improvement in symptoms whether by an individual's global impression or more formally by use of a validated instrument is an important factor. However, some persons with significant OSA are asymptomatic, and symptom improvement would not be expected. Because mild OSA is defined as an AHI ≥5/hour, a reduction in AHI below this level is considered a complete therapeutic response. However, there is controversy regarding the utility of the AHI as an index of OSA severity [79]. Thus, from a patient care perspective, can a reduction in AHI from >50/hour to 10/hour be considered a success if the patient's symptoms resolve? An AHI equal to 10/hour still is considered as mild OSA. Many clinicians would be satisfied with such a response and would be reticent to pursue additional treatment options despite the presence of residual OSA. A more complex issue is whether usage of PAP for at least 70% of nights for more than 4 hours per night defines treatment success. This amount of usage has been adopted by the Centers for Medicare and Medicaid Services (CMS) and many insurers as the minimum criteria for reimbursement for PAP therapy [76]. Unfortunately, it also has been adopted by many clinicians as the metric for treatment success. If one assumes that the amount of healthy sleep for an adult should be at least 7 hours per night [80], then over 1 month, the total amount of sleep achieved should be 210 hours. However, if a person only meets minimum CMS criteria, then the usage of PAP will only be 85 hours or 40.4% of optimum use! This

calculation suggests that successful treatment should not be defined as only meeting minimum CMS criteria. Another issue is whether individuals who use PAP less than the CMS minimum will benefit from PAP. From a therapeutic perspective, it is illogical to believe that use of PAP for slightly less than 4 hours will be ineffective treatment in comparison to slightly more than 4 hours. Data examining changes in the ESS as a function of PAP usage would suggest that improvement and hence treatment success is more of a continuum rather than a threshold effect [8, 81].

1.4 Summary

Continuous positive airway pressure is indicated to treat clinical symptoms and a variety of medical conditions resulting from or occurring in association with OSA. If used for adequate amounts of time, it usually improves clinical symptoms. It also may prevent or treat some comorbid medical conditions such as hypertension and type 2 diabetes. Treatment success can be ascertained through a combination of subjective improvement in symptoms and objective documentation of adherence to therapy.

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