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ORIGINAL ARTICLE

Moving beyond empiric continuous positive airway pressure (CPAP) trials for central sleep apnea: a multi-modality titration study

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Abstract There is no universally accepted method to determine effective therapy for central sleep apnea (CSA). Continuous positive airway pressure (CPAP) applied acutely most often does not eliminate apneas and hypopneas. We hypothesized that the application of two or more therapeutic modalities after the diagnostic phase of polysomnography, a multi-modality titration study (MMTS), would identify a successful CSA treatment more often than a standard split-night study (SNS) and obviate the need for additional polysomnograms to determine a successful therapy. We retrospectively analyzed polysomnograms of patients diagnosed with CSA at our Sleep Disorders Center. We defined a therapy trial that resulted in an apnea–hypopnea index<10 with at least one treatment modality as a therapeutic success. One hundred fifteen patients with CSA were studied. Sixty-six patients (57.4%) underwent a SNS, and 49 patients (42.6%) underwent a MMTS. SNS yielded only 8/66 (12.1%) successes on the first night, whereas a MMTS yielded 19/49 (38.8%) successes (p=0.001, two-tailed Fishers exact). Patients who underwent a SNS eventually had similar rate of success as patients studied with MMTS (60.6 vs 63.3%, NS), but required more testing. Adaptive servo-ventilation was the most successful modality tested, yielding 36/46 (78.3%) successes. Trials of additional modalities following a failed trial of CPAP often produce a successful option that may guide therapy in patients with CSA. This approach may lead to establishing the diagnosis and treatment plans faster, while reducing unnecessary testing.

Keywords Central sleep apnea · Positive-pressure respiration · Ventilatory support · Oxygen inhalation therapy · Polysomnography · Split-night study

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Introduction

Improving the value of medical care is an imperative in an era when economic constraints mount over an aging population [1–3]. At the same time, the awareness and prevalence of sleep apnea has been increasing, resulting in increased utilization of polysomnography (PSG). To deliver high quality at reduced cost, instead of performing a diagnostic and a therapeutic polysomnogram over two nights, a combined diagnostic–therapeutic study (split-night study, SNS) is increasingly used when evaluating patients with suspected obstructive sleep apnea, the most common diagnosis in sleep medicine [4–7]. During a SNS, a titration trial of continuous positive airway pressure (CPAP) is added subsequent to the diagnostic component [5]. Application of a split-night protocol in obstructive sleep apnea (OSA) is now quite standard in many sleep centers, leads to decreased cost and decreased time to therapy compared with a two night process, and has no adverse effect on patient outcome [6, 8].

In contrast to the situation with OSA, there is presently no standardized approach to the treatment of central sleep apnea

(CSA) syndrome . CSA is known to be prevalent in specific patient populations such as patients with congestive heart failure (CHF) [9–11], but in many cases, this diagnosis is not suspected before PSG [11]. As a consequence, CSA is most frequently diagnosed on the basis of a PSG that is ordered for generically suspected sleep-disordered breathing. If a SNS protocol has been ordered for testing, once it is noted that CSA is present, a trial of CPAP is performed. However, there is a major difference between OSA and CSA in the responsiveness to CPAP therapy. CPAP is usually very effective in OSA; in contrast, in CSA, CPAP may result in attenuation of breathing events in a proportion of patients but typically leaves a residual apnea–hypopnea index (AHI) close to 20 [12–18]. As a consequence, CPAP applied during the therapeutic portion of the standard split-night PSG only infrequently results in acute abolition of the CSA. Several other treatment modalities such as oxygen [19–25], bi-level positive airway pressure (BPAP) [26–28], and adaptive servo-ventilation (ASV) [15, 29] have been used in management of patients with CSA with more success than CPAP. However, these modalities are significantly more costly than CPAP, which precludes their routine use as first-choice options in treatment of CSA.

Additionally, patients with CSA tend to have poorer subjective tolerance of CPAP therapy than patients with OSA [17, 18, 30–32]. Combining poor tolerance with low effectiveness of CPAP therapy may translate into frustration and poor follow-up and further delay in establishing the effective therapy. If one accepts that, similar to patients with OSA, it is desirable to demonstrate effective therapy in the sleep laboratory before recommending a prolonged treatment, it becomes important to determine how much testing is necessary to accomplish this goal.

Based on these premises, many of the sleep specialists in our group had adopted the practice of split-night protocol in patients with suspected CSA. The inclusion of one or more additional portions in the sleep study (multi-modality titration study [MMTS]) in cases of ineffectiveness of the first therapeutic modality (usually CPAP) in correcting the CSA was driven by the clinical observation of poor tolerance of CPAP by patients with CSA and was aimed to limit the "wasted" time for the treatment method that was not effective. In MMTS, as ineffectiveness of the first modality (usually CPAP) becomes apparent, a different treatment modality, e.g., BPAP, oxygen, or ASV therapy, is attempted sequentially for the remainder of the sleep study. This approach, although theoretically attractive, has never been formally evaluated.

In this study, we retrospectively analyzed polysomnographic data on consecutive patients with CSA and compared acute effectiveness of the SNS protocol with a MMTS in demonstrating a successful option for therapy. We speculated that MMTS may allow establishing the successful therapy faster than SNS and lead to less testing. We also analyzed which treatment modalities were acutely successful in patients with CSA.

Materials and methods

Definitions

We defined CSA syndrome as (1) CSA index>5 and (2) CSA index higher than the combined obstructive and mixed apnea index. We considered a polysomnogram designed to have one diagnostic and one therapeutic portion a SNS and a polysomnogram with a diagnostic and possibility for more than one therapeutic portion a MMTS. Finally, therapeutic success was defined as a modality trial that resulted in reducing the AHI<10 by the last portion of a sleep study, provided that the total sleep time (TST) during this modality of the study was at least 30 min.

Patients

All patients were referred to the Mayo Clinic Sleep Disorders Center for suspected sleep-disordered breathing and were evaluated with PSG at our center. Patients were included in the study if they had CSA during the diagnostic portion of the PSG. We identified 117 patients with CSA through the retrospective analysis of sleep studies done between 1/1/2003 and 06/30/2006. Two patients were excluded from the analysis because they only underwent a diagnostic study.

Study design

Through the review of individual medical records, we separated our CSA patients into those who received SNS as their first PSG vs those who received MMTS as their first night sleep study. We analyzed the rates of traditional SNS and MMTS among 115 patients with CSA and their efficacy in establishing the effective treatment.

Methods

CPAP titration CPAP titration was started at 5 cmH_2O. If obstructive apneas–hypopneas were present, pressure was titrated at 1 cmH_2O increments to eliminate them. Pressure was then maintained for 10 min to allow breathing to stabilize. If CSA activity was present, pressure was incremented by 1 cmH_2O by up to an additional 5 cmH_2O above 5 cmH_2O or the level controlling obstructive events. If increasing pressure did not relieve CSA, the pressure was titrated down to the level that most reduced apneas, hypopneas, and optimized respiratory-related arousals.

BPAP titration BPAP titration was started with the expiratory positive airway pressure (EPAP) set at or near the CPAP level that eliminated any obstructive apneas, hypopneas, and snoring. The inspiratory positive airway pressure (IPAP) was initially set 2–4 cmH_2O above the EPAP. The EPAP was subsequently titrated to eliminate residual apneas, while the IPAP was increased to eliminate hypopneas and hypoventilation. The IPAP and/or EPAP were adjusted 1 cmH_2O at 1- to 2-min intervals while trying to maintain and IPAP–EPAP difference of at least 2–3 cmH_2O until stable sleep and breathing was achieved. Maximum IPAP and EPAP were no greater than 20 and 15 cmH_2O, respectively. In bi-level positive airway pressure in spontaneous-timed (BPAP-ST) titration, the respiratory backup rate was set at or slightly below the patient's spontaneous awake respiratory rate (usually 10–14 breaths/min).

ASV titration ASV titration was started with the end expiratory pressure set at or near the CPAP level, which eliminated any obstructive apneas, hypopneas, and snoring. End expiratory pressure was adjusted up to a maximum of 10 cmH_2O to eliminate obstructive events. We used the default variable inspiratory pressure set by the manufacturer, varying 5–10 cmH_2O above the end expiratory pressure.

Oxygen titration Oxygen was administered via nasal cannula. The initial oxygen flow rate was 1 l/min, and this was increased by increments of 1 l/min up to the maximum specified in physician orders (usually 3–4 l/min) in an attempt to correct any hypoxemia (SaO_2<90%) and normalize the breathing pattern.

SNS protocol The first therapeutic modality (usually CPAP) was started between 2:30 A.M. and 3:00 A.M. if a TST of 120 min had been achieved (always trying for at least 30 min of supine sleep) and either (a) the AHI≥5, or (b) the respiratory related arousal frequency was ≥10 per hour during the diagnostic portion of testing.

MMTS protocol After the diagnostic portion, the first therapeutic modality (usually CPAP) was initiated according to split-night criteria defined above. When the first therapeutic modality was judged ineffective by the PSG technologist performing a sleep study, additional therapeutic modality trials were introduced according to the physicians order. The type and sequence of interventions were determined by the ordering physician.

Follow-up and adherence monitoring Our patients were informed of the results of their tests by the reviewing sleep specialist, and a treatment plan was decided during that report visit. The report visit typically took place within 48 h of the diagnostic test (median <24 h). All patients were invited to follow-up at the Sleep Disorders Center 1 month after the treatment prescription. Assessment of adherence relied on adherence monitors built into the positive airway pressure (PAP) machines. We recorded the average time per night that the PAP therapy was used.

Analysis

Patients were grouped according to whether they had a SNS or MMTS on the first night of evaluation. All categorical data are presented as number (percent), and all continuous data are presented as medians and interquartile range (IQR). Continuous variables were compared using Mann–Whitney *U* test, and discrete variables were compared using two-tailed Fisher's exact test.

Results

Patient population

Demographic and polysomnographic data of the 115 patients with CSA are presented in Table 1. One hundred (87.0%) patients were male. Fifty-one patients (44.3%) carried diagnoses of CHF. Median AHI was 50 (IQR 30.5–66.5), and 87 (75.7%) patients had AHI≥30. The majority of patients (85/115, 73.9%) had a Cheyne–Stokes breathing pattern during the diagnostic portion of the sleep study.

Initial evaluation and success rates

Sixty-six patients (57.4%) underwent a traditional SNS, and 49 patients (42.6%) underwent a MMTS (Fig. 1). During the study period, there was minimal change in ordering practice among physicians of our center. Seven of 14 (50%) studies in 2003, 17/53 (32.1%) studies in 2004, 7/15 (46.7%) studies in 2005, and 18/33 (54.5%) studies in 2006 were ordered as MMTS. One hundred and six of 115 patients (92.2%) had CPAP as their first therapeutic modality. Patients who underwent a SNS did not differ from the patients who underwent a MMTS in age (p=1), body mass index (p=0.19), initial AHI (p=0.41), or the percentage of patients with history of CHF (p=0.15). The median TST (IQR) during the diagnostic portions of a SNS and MMTS were 145.3 (125.7–168.8) and 137.5 (122.0–155.0) minutes, respectively (p=0.14, Mann–Whitney *U* test). The median TST during the first therapeutic portion of a SNS and MMTS were 139.3 (105.0–193.5) and 55.5 (33.0–94.0) minutes, respectively (p<0.0001). The lower therapy trial time during MMTS reflects the time needed for the technologist to determine that the first modality tried

Table 1 Demographic and polysomnographic data and etiology of CSA

Variable	Value (%) median (IQR)		*p* value
	Split night study (*n*=66)	Multi-modality titration study (*n*=49)	
Age	69 (57–76)	70(60–77)	1.0**
Female gender (%)	16.7%	8.2%	0.14*
Diagnosis			
Primary CSA	21 (31.9%)	9 (18.4%)	0.08*
Cheyne–Stokes pattern	45 (68.1%)	40 (81.6%)	0.08*
History of CHF	26 (38.8%)	25 (51.0%)	0.15*
Apnea–hypopnea index	51.0 (31.0–70.5)	47.0 (30.0–64.0)	0.34**
Central apnea index	15.0(8.0–28.3)	15.0 (6.0–27.0)	0.88**
Arousal index	52.2 (34.6–73.6)	41.8 (33.0–67.4)	0.26**
Breathing-related arousal index	40.4 (22.9–66.1)	35.9 (23.2–54.0)	0.63**

CSA Central sleep apnea, *IQR* interquartile range, *CHF* congestive heart failure
**p* values calculated by Fisher's exact test
***p* values calculated by Mann–Whitney *U* test

would not effectively eliminate sleep-disordered breathing. The median TST during the second therapeutic portion of a MMTS was 80.0 (37.0–129.5) minutes. Among 49 patients who had a MMTS, 12 (24.9%) had more than two therapeutic portions during their initial sleep study. The percentage of rapid eye movement (REM) sleep during the therapeutic part of the SNS 13.7% (8.2–21.3%) was not significantly different than the percentage of REM sleep during the final therapeutic part of the MMTS (11.4%, 0.0–25.1%, $p=0.27$, Mann–Whitney *U* test).

The traditional SNS protocol yielded 8/66 (12.1%) successes on the first night, whereas the MMTS yielded 19/49 (38.8%) successes ($p=0.001$, two-tailed Fishers exact). CPAP followed by CPAP with O_2 (13/49, 26.5%), CPAP followed by O_2 (9/49, 18.4%), and CPAP followed by BPAP-ST (8/49, 16.3%) were the most common protocols used in the MMTS group. Of 92 patients who were not successfully treated the first night, 63 (44 studied by SNS and 19 studied by MMTS) underwent a second study. Eventually, 40/66 (60.6%) studied with SNS and 31/49 (63.3%) studied with MMTS ($p=0.85$, Fisher's exact test) reached a successful therapy. When analyzed as a subgroup, 85 patients with Cheyne–Stokes pattern of breathing had similar findings to the whole group, with 4/45 (8.9%) patients studied with SNS and 17/40 (42.5%) with MMTS protocol achieving successful titration on the first night (Fisher's exact test, $p<0.001$), and 27/45 (60%) of patients with SNS and 28/40 (70%) of patients with MMTS achieving success at the end of the evaluation (Fisher's exact test, $p=0.23$).

The median delay to successful therapy among patients studied with the SNS protocol was 8 (2–53) days. Among all patients who did not reach a therapeutic success, the median residual AHI at the last therapeutic portion of sleep study was 18 (14.5–31) in patients who underwent a MMTS and 28.5 (21–34.5) in patients who underwent a traditional SNS ($p=0.56$, two-tailed, Mann–Whitney *U* test).

CSA pattern is observed primarily during the non-rapid eye movement (NREM) sleep. To assure that the observed success rates are not due to the lower percentage of NREM sleep, we calculated the percentage of NREM sleep during the individual treatment episodes and the NREM-specific AHI. Although NREM was significantly more prevalent during the unsuccessful than during the successful treatment episodes (92.7% [80.5–100%] vs 84.4% [78.7–90.8%] of TST, respectively, $p<0.001$), the NREM-specific AHI remained significantly lower during the successful episodes (4 [1–9]) than during the unsuccessful episodes (23 [17–36], $p<0.001$, Table 2).

Successful modalities and prescribed treatments

Among modalities tested, ASV was the most successful therapy (36/46, 78.3%) in our patients. Acute efficacy with specific modalities was similar in the SNS and MMTS groups (Table 3). Diagnostic and therapeutic evaluation resulted in prescription of some form of therapy in 109/115 (94.8%) patients. Patients who underwent a SNS were most frequently prescribed CPAP (22/66, 33.3%), ASV (18/66, 27.3%), and BPAP-ST (11/66, 16.7%), whereas patients who underwent a MMTS were most frequently prescribed ASV (11/49, 22.4%), BPAP-ST (10/49, 20.4%), and O_2 (9/49, 18.4%; Table 3). Overall, 28/66 (42.4%) of patients studied with SNS and 28/49 (57.1%, $p=0.09$, Fisher's exact test) of patients studied with MMTS were prescribed a modality found acutely successful during their evaluation.

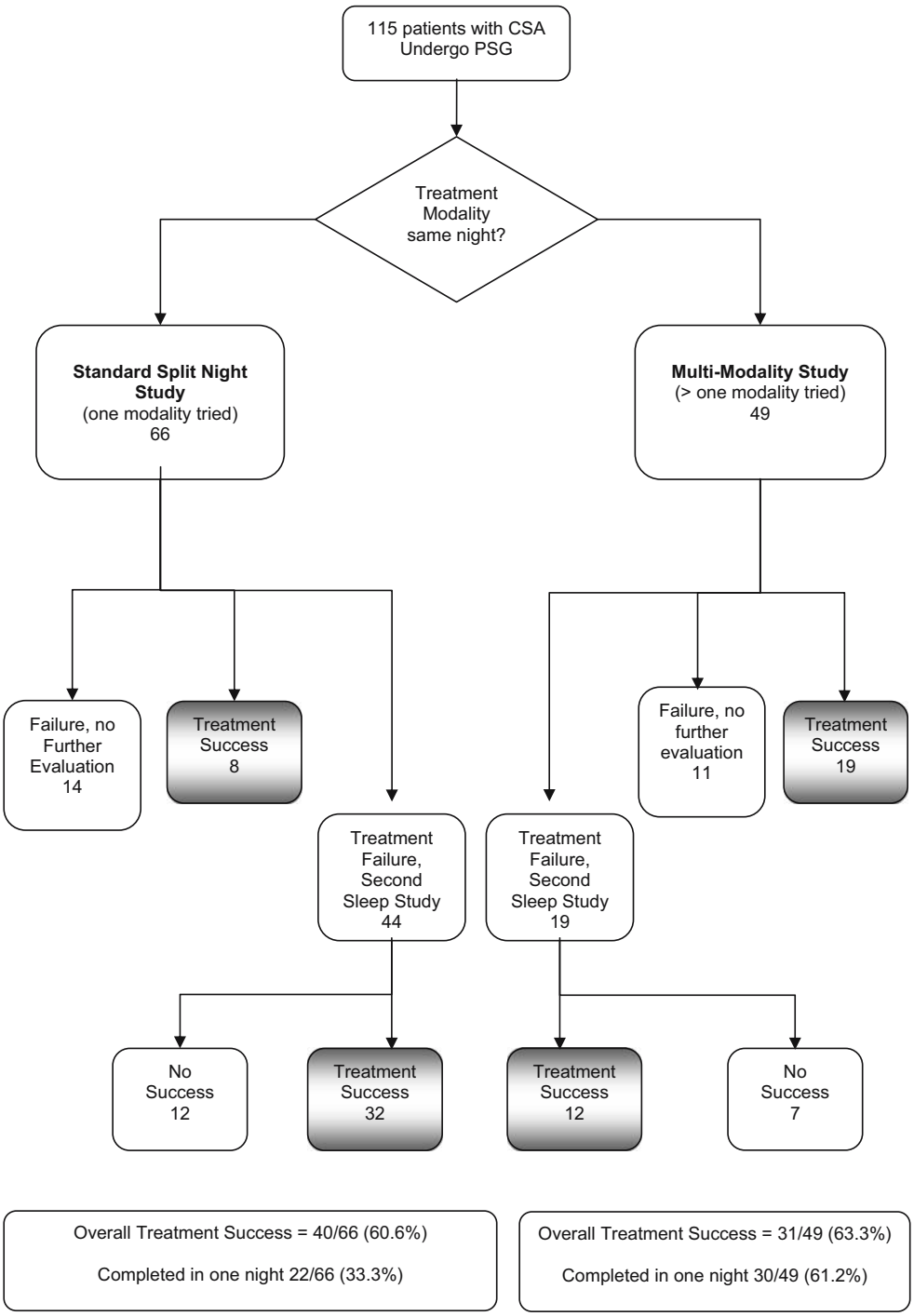

Fig. 1 Outcomes of CSA patients undergoing polysomnographically directed therapy trials

Table 2 Percentage of NREM sleep and the sleep stage-specific apnea–hypopnea index during successful and unsuccessful treatment episodes

	Success	No success	*p**
Number of episodes	95	197	N/A
NREM as per cent of TST (%)	84.4 (78.7–90.8)	92.7 (80.5–100)	<0.001
AHI during NREM (1/h)	4.0 (1.0–9.0)	23.0 (17.0–36.0)	<0.001

NREM Non-rapid eye movement sleep, *TST* total sleep time, *AHI* apnea–hypopnea index, *N/A* not applicable
*Compared by Mann–Whitney *U* test

Table 3 Success rates for different treatment modalities

Treatment modality	Successful/tried[a]		Final prescription (number of patients, % of group)	
	Split-night study (n=66)	Multi-modality titration study (n=49)	Split-night study (n=66)	Multi-modality titration study (n=49)
O_2	4/6 (66.7%)	8/17 (47.1%)	5 (7.6%)	9 (18.4%)
CPAP	1/59 (1.7%)[b]	2/47 (4.3%)[c]	22 (33.3%)	5 (10.2%)
CPAP + O_2	2/10 (20.0%)	8/25 (32.0%)	3 (4.5%)	7 (14.3%)
BPAP-S	0/9 (0%)	0/16 (0%)	0	0
BPAP-S + O_2	0/1 (0%)	0/2 (0%)	1 (1.5%)	0
BPAP-ST	13/19 (46.3%)	8/22 (36.3%)	11 (16.7%)	10 (20.4%)
BPAP-ST + O2	2/7 (28.6%)	4/6 (66.7%)	2 (3.0%)	5 (10.2%)
ASV	21/26 (80.8%)	15/20 (75.0%)	18 (27.3%)	11 (22.4%)

ASV Adaptive servo-ventilation, *BPAP-S* bilevel positive airway pressure in spontaneous mode, *BPAP-ST* bilevel positive airway pressure in spontaneous-timed mode, *CPAP* continuous positive airway pressure

[a] Eight patients (6.8%) did not receive any therapy at the conclusion of their evaluation.

[b] Two patients with SNS had a CPAP-O_2 trial, two had a BIPAP-ST trial, two had an ASV trial, and one had an O_2 trial as their first therapeutic modality.

[c] One patient with MMST had an O_2 trial and one had a CPAP-O_2 trial as their first therapeutic modality.

Follow-up

Follow-up data were available in 36/72 (50.0%) patients who had a treatment success during their evaluation and 23/45 (51.1%) patients whose treatment was not acutely successful. This rate of follow-up is fairly typical in our patient population, as 58/115 (50.4%) of them came for evaluation from outside of our state. There were no differences in age (p=0.83), gender (p=1), or initial AHI (p=0.97) between the patients who were available for follow-up and those who did not.

Data on treatment adherence were available in 37/59 patients (26/71, 36.6% with treatment success and 11/44, 25.0% with no success) who were prescribed a PAP system and reported for a follow-up visit. Overall, adherence with PAP therapy was similar in patients who were initially diagnosed with a SNS to that of patients diagnosed with a MMTS protocol (6.5 [5.0–7.4] vs 7.0 [3.7–7.7] hours per night, respectively, p=0.76, two-tailed, Mann–Whitney U test). Adherence with PAP therapy was significantly better in patients who had a treatment success during their evaluation than in patients whose treatment was not acutely successful (7.2 [5.8–7.7] vs 2.5 [2.1–5.5] hours per night, respectively, p<0.005, two-tailed, Mann–Whitney U test).

Discussion

We have shown that incorporating an additional therapeutic portion in the initial sleep study in patients with CSA syndrome leads to higher rates of acutely successful treatment. We have also shown that, by applying a MMTS protocol, as compared to SNS, the significantly higher proportion of patients with CSA can complete the evaluation in one night.

Normalization of breathing abnormalities is an accepted goal of treatment in OSA. In contrast, there is no consensus on what should be considered an adequate response to treatment in CSA. Several research and clinical protocols reported therapeutic AHIs in the range of <5/h [25], 5–10/h [20, 21, 28, 32], or even 10–20/h [12, 22, 24, 33], which represented an improvement by 50–67% from the pretreatment values. This degree of AHI response was usually associated with a number of positive metabolic, physiologic, and clinical outcomes: decreased excretion of catecholamine metabolites [34], decreased brain natriuretic factor [34], improved left ventricular ejection fraction [13, 14, 33, 35], improved ventilatory efficiency during exercise [21, 33], improved peak oxygen consumption [21], improved symptoms of CHF [36], and improved quality of life [32]. These salutary responses in cardiovascular physiologic outcomes promoted the concept that CPAP therapy might benefit patients with CSA even when breathing abnormalities are not normalized. However, in a recent prospective randomized trial, empirically adjusted CPAP did not normalize sleep-disordered breathing, leaving a residual AHI of approximately 20 and did not reduce cardiovascular events [12]. In contrast, in a recent trial comparing treatment of CSA over 6 months, both AHI and cardiovascular endpoints were improved in patients treated with ASV, a modality demonstrating acute improvement in AHI, but the cardiovascular improvements were not seen in patients treated with CPAP [32].

Based on these studies, we can reasonably ask if the goal for treating CSA should not be more similar to that for OSA, namely, normalization, rather than improvement of sleep-disordered breathing? In patients with OSA, even

mild elevations of AHI (5–15/h) are still associated with an increased risk for hypertension [37, 38] and more frequent cardiovascular events [39, 40]. In addition, patients with OSA receiving suboptimal treatment do not benefit from reduction in blood pressure [41] and have higher rates of cardiovascular events [42]. Many of the pathophysiologic pathways linking adverse cardiovascular and metabolic effects with sleep-disordered breathing are probably shared between OSA and CSA patients. Although these data cannot be directly extrapolated onto the CSA patient population, they raise suspicion that even mild residual sleep-disordered breathing might be associated with adverse health outcomes. Therefore, we decided to use an arbitrary target AHI of <10/h to define treatment success, rather than any per cent improvement, mimicking expected treatment goals for OSA and some other CSA trials [12, 32].

Finally, we acknowledge that it is not known how the acute response to therapy for CSA during titration night relates to any long-term improvements in sleep-disordered breathing. In most reports published so far, acute titration of PAP in patients with CSA aimed for "significant improvement" in AHI rather than targeting any specified range [12, 14, 32, 35, 36]. Studies originating from the Toronto group employed an empiric titration protocol spread over two to three nights, aimed to increase the CPAP pressure to 10 cmH_2O or the highest tolerated pressure [12, 14, 35, 36] It has long been thought that, although patients with CSA have suboptimal acute improvement in AHI, breathing abnormalities substantially improve over time in treatment compliant patients. However, recent evidence suggests that the incompletely reduced AHI remains stable or worsens among CSA patients treated with CPAP when measured at 3 and 6–24 months after the beginning of therapy [12, 32]. Poor efficacy of CPAP over 1–2 weeks of therapy that was reported in some earlier studies was most likely due to low level of PAP used and not to the insufficient follow-up time [16, 18]. Thus, it seems that a poor initial response to CPAP therapy may be predictive of longer-term inadequate control of sleep-disordered breathing.

Using a MMTS protocol in evaluation of patients with CSA resulted in a comparable rate of success in treating CSA and a comparable adherence with the prescribed therapy as using a SNS protocol. However, patients studied with MMTS protocol reached the successful therapy faster and required less testing nights than patients studied with SNS protocol. Additionally, prolonging the evaluation beyond one night may lead to reluctance to complete a second night of testing in patients who had an unsuccessful CPAP titration during their SNS night. The burden of having to repeat the study and an additional cost may contribute to such reluctance. Finally, although retrospective and, therefore, subject to selection bias, our data indicate that patients who reached treatment success during the evaluation had higher adherence than patients whose therapy was not acutely successful. Confirming the results of other studies [15, 32], ASV was found by us to be the modality offering the highest acute effectiveness in the treatment of CSA.

This study has several important limitations. We decided to base our diagnosis of CSA solely on the polysomnographic data and included all patients with CSA, irrespective of its etiology. It is conceivable that patients with different etiologic basis of their CSA respond differentially to treatment modalities. Furthermore, patients were not randomized between SNS and MMTS protocols. Furthermore, our follow-up data are not complete; we were able to establish the objective PAP adherence in approximately half of our patients. Our definition of a successful trial of therapy is limited by being only 30 min long. It is doubtful that patients uniformly experienced REM during such a period, but as we have shown, even the NREM portions of sleep during successful segments show improved control of breathing abnormalities compared with unsuccessful treatments. In a way, analogous to a successful SNS CPAP trial, the successful pressure is often chosen based upon only a small segment of time at the treatment pressure. This is often acceptable because the reviewer has not only the knowledge of what the patient's sleep looks like at the treatment pressure, but what it looked like at all other pressures and modalities. Finally, we do not have any data on longer-term effectiveness of therapy following a SNS or MMTS study protocols.

In summary, we have shown that, if the goal is to determine a treatment modality that normalizes breathing abnormalities in patients with CSA, a MMTS leads to establishing an effective therapy faster and more frequently than a SNS. We confirmed that ASV was the most successful treatment modality in achieving acute control of the CSA. We propose that these results warrant that a MMTS protocol should be considered when CSA is diagnosed during the first portion of diagnostic testing.

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