Original Article

The success rate of split-night polysomnography and its impact on continuous positive airway pressure compliance

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Abstract:

OBJECTIVES: With the increased volume of referrals of patients with obstructive sleep apnea (OSA) for sleep studies, there is a great need for alternatives of the standard two-night polysomnography (PSG) like split-night PSG. Therefore, we conducted this study to determine the success rate of continuous positive airway pressure (CPAP) titration during split-night PSG, and to determine the predictors of titration success and the impact on subsequent CPAP compliance in Saudi patients with OSA.

METHODS: This is a prospective cohort study that included consecutive patients who were diagnosed with OSA and underwent a split-night PSG ($n = 454$). A subgroup of patients who used CPAP therapy, agreed to come for follow-up after 4 and 10 months ($n = 130$). This subgroup was compared with a matched group of OSA patients who underwent a two-night sleep study protocol ($n = 80$).

RESULTS: The study group had a mean age of 48.7 ± 13.3 years, body mass index (BMI) of 37.5 ± 10.1 kg/m^2 and apnea hypopnea index of 58.4 ± 35.0 events/h. Successful CPAP titration was achieved in 350 (77%) patients. In a full adjusted model, "BMI >35 kg/m^2" and "known cardiac disease" remained significant predictors of a lower success rate of CPAP titration. After 10 months, 88% of the patients in the split-night protocol met the set criteria for good compliance versus 85% in the two-night protocol.

CONCLUSION: Split-night protocol is an effective protocol for diagnosing OSA and titrating CPAP. CPAP compliance rate showed no difference between the split-night and the two-night protocols.

Key words:

Continuous positive airway pressure, obstructive sleep apnea, polysomnography, split-night sleep study

Obstructive sleep apnea (OSA) is a chronic disease characterized by recurrent apneas and hypopneas during sleep. OSA is a common medical problem associated with significant complications including daytime sleepiness, motor vehicle accidents, ischemic heart disease, hypertension, and stroke.[1] Moreover, it leads to increased utilization of health care resources.[2] Recent data estimated the prevalence of moderate to severe OSA to range from 10% to 17% in middle-aged and elderly men.[1] In Saudi Arabia, one in three middle-aged men is at risk for OSA.[3] The diagnosis and treatment of OSA relies on documentation of apneas and hypopneas in a diagnostic study, and subsequent elimination of respiratory events using continuous positive airway pressure (CPAP) titration in a therapeutic study. And thus, the gold standard procedure for diagnosis and treatment of OSA is a two-night attended polysomnography (PSG) as per the American Academy of Sleep Medicine (AASM) guidelines.[4] The first night is used to diagnose OSA and the second night is used for CPAP titration. However, with the increased public and physicians' awareness of sleep disordered breathing, more referrals for diagnostic, and therapeutic sleep studies have been noticed in Saudi Arabia in the last few years.[5] Nonetheless, the number of sleep laboratories during the same time period has not coped with the requirement.[6] Such discrepancy resulted in increased economic burden on the health care system as well the patients' waiting list and subsequently resulted in delayed OSA diagnosis and treatment.[6,7]

Both diagnostic and therapeutic studies can be combined in one study, where the first half is used for OSA diagnosis and the second half for CPAP titration. This protocol is called split-night protocol or study. Split-night sleep study serves several advantages. It decreases the waiting time, more convenient for patients as they need to spend one night only in the sleep laboratory and decreases the cost on the health care system.[8]

Cultural factors have been shown to affect the success of sleep studies, CPAP titration trials, and CPAP compliance.[9] Therefore, data reported

in Western societies about split-night sleep studies, CPAP titration, and CPAP compliance cannot be extrapolated to Saudi patients with OSA. No study has addressed the utility of split-night sleep studies among Arabs in general and Saudis in particular and its subsequent impact on long-term CPAP compliance.

Therefore, we conducted this study to determine the success rate of CPAP titration during split-night sleep study, to determine the predictors of success and the impact on subsequent CPAP compliance after 4 and 10 months in Saudi patients with OSA.

Methods

This is a prospective cohort study that included consecutive patients (>18 years) newly diagnosed with OSA in the Sleep Disorders Center (SDC), between June 2011 and January 2013. Exclusion criteria included patients who received sedatives or narcotics, chronic neuromuscular diseases, decompensated heart failure, daytime hypercapnia ($PaCO_2$ >45 mmHg), and patients with other sleep disorders. Patients were assessed by a sleep physician before sleep study where demographic, clinical data, and comorbid conditions were recorded. Patients had not had prior PSG. For assessment of daytime sleepiness, the Epworth sleepiness scale was used, which is a validated questionnaire that has eight items to assess the likelihood of dozing in a variety of daily living situations.[10]

The study was approved by the ethics committee in our hospital and informed consent was obtained from all participants.

Study protocol

All consecutive patients with a clinical suspicion of OSA underwent PSG with the intention to perform a spilt-night protocol. A subgroup of patients who used CPAP therapy, agreed to come for follow-up after 4 and 10 months (n = 130). CPAP compliance in this group was compared with CPAP compliance of 80 patients who participated in another contemporary study and underwent a two-night sleep study protocol, a diagnostic study followed by a therapeutic study.[11] The two groups were matched for age, sex, BMI, oxygen desaturation index, and apnea hypopnea index (AHI). All patients had the same education and training on CPAP machines and were enrolled in the same follow-up program.

Polysomnography recording

Standard in-lab overnight PSG was performed to monitor brain activity (electroencephalogram with electrodes placed at C3A2, C4A1, O1A2, O2A1, F3A2, and F4A1), muscle tone (electromyogram of the chin and both legs), eye movements (electrooculogram, heart rate (electrocardiogram), oxygen saturation (finger pulse oximeter), chest and abdominal wall movements (thoracic and abdominal belts, respectively), airflow (thermistor and nasal prong pressure transducer), and snoring (microphone). The PSG recording was performed using Alice® 6 diagnostic equipment (Respironics Inc., Murrysville, PA, USA). A minimum recording time of 6 h with a good signal was required.

Polysomnography scoring

The analysis and scoring of sleep and breathing were performed manually by certified sleep technologists in accordance with established criteria.[12] Apnea was defined as a drop in the peak thermal sensor excursion ≥90% of baseline for at least 10 s. The event was scored as obstructive apnea in the presence of continued respiratory effort and central apnea if associated with absent inspiratory effort throughout the entire period of absent airflow. Hypopnea was scored if there was a reduction in airflow of ≥50% of baseline that lasted for at least 10 s and resulted in either a ≥3% decrease in oxygen saturation from the pre-event baseline or an arousal. The AHI score was defined as the number of apneas and hypopneas per h of sleep and was calculated for the entire sleep duration. OSA was defined according to the International Classification of Sleep Disorders.[13] The desaturation index was defined as the number of desaturation (≥3%) events per h of sleep. Sleep efficiency was calculated as the (total sleep time/time in bed) × 100. The severity of OSA was classified based on AHI values as follows: 5-15, mild OSA; 15-30, moderate OSA; and >30, severe OSA.[14]

Continuous positive airway pressure titration protocol

All patients had been informed that CPAP might be applied during the night, and had been given educational materials explaining CPAP. After 2.0-3.5 h of baseline sleep for diagnostic purposes, we applied CPAP to the patients for the remainder of the night. The decision to start CPAP titration was based on an AHI of at least 40/h during a minimum of 2 h of diagnostic PSG, or an AHI of <40/h, based on clinical judgment (e.g., if there are also repetitive long obstructions and major desaturations).[15] Patients with severe OSA manifested by significant oxygen desaturations below 80% or with cardiac arrhythmias had CPAP applied earlier. CPAP titration was carried out for ≥3 h.[15] CPAP titration was performed in accordance with the AASM guidelines.[15] CPAP titration outcome was categorized into (1) successful, if the titration met the AASM criteria for optimal or good CPAP titration; and (2) unsuccessful titration if the titration did not meet the above criteria.[15] Both groups (the split-night group and the two-night group) had an identical CPAP titration algorithm.[15]

Continuous positive airway pressure compliance

Continuous positive airway pressure was considered initially accepted if a patient described his/her sleep on CPAP under PSG monitoring in the SDC as being good.[16] CPAP compliance was assessed objectively by downloading machine-on time tracking data from CPAP machines. CPAP users were categorized as being good users if they used CPAP regularly for more than 4 h/night for >70% of the recorded period; or if they used CPAP more than 2 h/night and have subjective improvement in OSA-related symptoms such as quality of life.[17] Those who did not meet the above criteria were labeled as nonusers.[17]

Statistical analysis

Data are presented as mean ± standard deviation or number (n%). For a comparison of categorical variables, Chi-square test was used, and for comparing continuous variables Student's t-test was used. To explore predictors of success of split-night sleep study, a univariate logistic regression model was used in a preliminary analysis; one explanatory variable was tested in the model at a time. Subsequently, variables with significant P values were further evaluated using a multivariate logistic regression model. $P < 0.05$ was considered statistically significant. Standard statistical software (IBM SPSS 21.0

Armonk, New York, USA) was used for the data management and analytical activities.

Results

During the study period, 454 patients (67% males) were recruited with a mean age of 48.7 ± 13.3 years, body mass index (BMI) of 37.5 ± 10.1 kg/m^2 and AHI of 58.4 ± 35.0 events/h. Table 1 shows the general characteristics of the participants. Successful CPAP titration was achieved in 350 (77%) patients. Success rate was 59.4%, 84.3%, and 77.5% in mild, moderate, and severe OSA, respectively.

Table 2 shows a comparison between patients with successful and unsuccessful titration. The unsuccessful titration group had higher BMI and lower sleep efficiency.

Table 3 shows the independent predictors of successful split-night sleep study. Univariate analysis identified male sex and sleep efficiency as predictors of higher success and BMI >35 kg/m^2 and "known cardiac disease" as predictors of lower success. BMI >35 kg/m^2 and "known cardiac disease" remained significant predictors of CPAP compliance in a fully adjusted model.

Table 4 shows the data of patients who underwent two-night sleep study protocol. CPAP acceptance in the split-night group was 89% and in the two-night protocol was 86%. CPAP compliance data revealed that 88% (n = 108 out of 130) of patients who underwent the split-night sleep study met the criteria for good users after 10 months versus 85% (n = 68 out of 80) in the group who underwent the two-night sleep study protocol.

Discussion

Limited studies have evaluated the utility of split-night sleep study and none has been conducted among Saudi patients. Moreover, very limited data are available on the impact of split-night study protocol on long-term CPAP compliance. This study is one of the largest reported studies that followed recruited patients prospectively for 10 months. It shows that the success rate of split-night studies in OSA patients is very good. Moreover, CPAP compliance among patients in split-night protocol was comparable to that in the two-night protocol at the end of the study.

The concern raised against conducting a split-night protocol is whether the PSG profiles in the first and second part of the night are similar, which in turn may underestimate or overestimate the severity of OSA. In a study that compared the PSG profiles obtained in the first and second parts of the night, the investigators demonstrated that in patients who progressed into stage rapid eye movement sleep during the first part of the night, the AHI during split-night PSG was similar to the AHI during the full-night PSG.[18] Moreover, in a retrospective study that examined diagnostic data collected during the first half of the night, the investigators evaluated 48 consecutive full-night diagnostic sleep studies by separately analyzing data collected during the first half of the night and compared it with data collected over the whole night.[5] They compared respiratory events in the first half of the night with events in

Table 1: General and demographic characteristics of the participants

Characteristics	Mean ± SD/ *n* (%)
Age (year)	48.7±13.3
Sex (male)	304 (67)
BMI (kg/m^2)	37.5±10.1
ESS	9.92±5.7
Total sleep duration during titration (min)	184.72±28.4
AHI (events/h)	58.4±35.0
Mild OSA (AHI 5-15)	33 (7.3)
Moderate (AHI 15-30)	83 (18.3)
Severe (AHI >30)	338 (74.4)
Desaturation index (events/h)	33.15±34.7
Lowest recorded nSaO$_2$ (%)	77.76±14.1
Arousal index (arousals/h)	60.8±33.7
Successful CPAP titration	
All patients	350 (77)
Mild OSA	18 (55)
Moderate OSA	70 (84.3)
Severe OSA	262 (77.5)

BMI = body mass index, ESS = Epworth sleepiness score, AHI = apnea hypopnea index, CPAP = continuous positive airway pressure, nSaO$_2$ = nocturnal oxygen saturation, OSA = obstructive sleep apnea, SD = Standard deviation

Table 2: Comparison between patients with successful and unsuccessful CPAP titration

Variables	Mean ± SD/*n* (%)		*P*
	Successful titration (*n* = 350)	Unsuccessful titration (*n* = 104)	
Age	48.5±12.8	49.35±14.9	0.6
BMI	36.4±9.2	41.09±12.0	0.001
Neck	15.8±1.6	16.02±1.55	0.2
ESS	10.1±5.71	9.3±5.5	0.2
pH	7.4±0.03	7.4±0.04	0.3
PCO_2	43.22±4.0	43.47±3.2	0.9
PaO_2	78.89±15.66	77.3±13.0	0.2
HCO_3	24.4±4.7	24±4.1	0.1
TSH	3.7±5.7	3.7±3.1	0.2
FT4	14.6±3.2	14.7±2.9	0.9
Sleep efficiency	74.2±15.9	67.3±18.8	0.001
N1	12.4±16.0	13.08±16.0	0.7
N2	72.2±14.8	69.4±16.3	0.08
N3	1.9±5.4	3.42±7.4	0.1
REM	11.8±10.3	13.5±11.5	0.2
AHI	59.14±35.7	55.69±32.72	0.6
AHI-NREM	57.69±37.88	54.44±34.73	0.6
AHI-REM	58.23±31.52	59.56±31.5	0.8
Central apnea index	1.52±5.91	2.35±7.11	0.2
Obstructive apnea index	11.76±22.65	7.13±15.92	0.1
Mixed apnea index	2.01±8.02	1.53±8.54	0.7
Hypopnea index	43.88±29.58	44.37±25.9	0.4
Lowest recorded nSaO$_2$ (%)	77.63±14.37	78.22±12.94	0.8
Arousal index	61.37±34.27	58.88±31.73	0.8

AHI = apnea hypopnea index, BMI = body mass index, ESS = Epworth sleepiness score, N1 = stage N1 sleep, N2 = stage N2 sleep, N3 = stage N3 sleep, CPAP = continuous positive airway pressure, nSaO$_2$ = Nocturnal oxygen saturation, NREM = non-rapid eye movement sleep, REM = rapid eye movement sleep, SD = Standard deviation, TSH = Thyroid stimulating hormone

Table 3: Univariate binary logistic regression analysis to predict successful CPAP titration

Predictors	*P*	B (log odds)	OR (95% CI)
Univariate model			
Sex (male)	0.049	0.456	1.578 (1.002-2.486)
BMI	<0.001	−0.042	0.958 (0.938-0.979)
BMI ≥35	<0.001	−0.055	0.964 (0.922-0.971)
Sleep efficiency	<0.001	0.023	1.023 (1.010-1.036)
Known cardiac disease	0.003	−1.129	0.323 (0.152-0.687)
Multivariate model			
BMI ≥35	0.040	−0.048	0.953 (0.918-0.989)
Known cardiac disease	0.012	−0.902	0.406 (0.171-0.962)

BMI = Body mass index, CI = Confidence interval, OR = Odd ratio, CPAP = Continuous positive airway pressure

Table 4: The main characteristics of patients who underwent the split-night protocol and patients who underwent the two-night protocol

Variables	Split-night protocol (*n* = 454)	Two-night protocol (*n* = 80)
Age	48.7±13.3	51.86±12.14
Sex (male)	304 (67)	48 (60)
BMI	37.5±10.1	38.38±10.58
ESS	9.92±5.67	10.56±6.05
AHI	58.4±35.0	63.69±39.25
Arousal index	60.8±33.69	63.87±35.73
Successful CPAP titration[$]	350 (77)	64 (80)
	Split-night protocol* (*n* = 130)	Two-night protocol (*n* = 80)
Accepted CPAP titration in the SDC*	116 (89)	69 (86)
Good CPAP users after 4 months*	125 (96)	78 (97.5)
Good CPAP users after 10 months*	108 (88)	71 (89)

*The data are presented for patients who agreed to participate in the CPAP follow-up part of the study (*n* = 130 patients), [$]Those who met the American Academy of sleep medicine criteria for optimal or good titration, BMI = body mass index, ESS = Epworth sleepiness score, AHI = Apnea hypopnea index, CPAP = Continuous positive airway pressure, SDC = Sleep disorders center

the entire night and reported no significant differences in apnea index, AHI or desaturation index.[5]

We demonstrated that CPAP titration using split-night protocol is as effective as the two-night protocol. Our results concur with Yamashiro and Kryger[19] who studied 107 patients with OSA and suggested that a split-night protocol could be as effective in reducing the AHI as a two-night titration protocol particularly in patients with severe OSA (AHI was >40). McArdle *et al*.[20] reported similar findings in a study of 138 patients. Hence, the proper utility of split-night sleep study protocol will result in significant reduction in the waiting list of patients needing to undergo diagnostic and therapeutic sleep studies. The findings of this study are of paramount importance in Saudi Arabia as the number of SDC in the country are limited, which resulted in long waiting lists.[2,21] Moreover, the utility of split-night protocol will result in significant cost saving. Iber *et al*.,[22] compared the cost effectiveness between split-night and two-night PSG and found a significant difference in favor of split-night study.

No clearly defined predictors of successful CPAP titration during split-night sleep study have been reported in the literature. This study showed that morbid obesity (BMI >35 kg/m^2) and the presence of cardiac disease are independent predictors of the lower success rate of CPAP titration. Although we excluded patients with hypercapnia, it is possible that some of the morbidly obese patients had an element of sleep hypoventilation. On the other hand, patients with heart failure are prone to develop central apnea, which may compromise CPAP titration.[23] To minimize this effect in the current study, we excluded patients with decompensated heart failure (based on clinical assessment). Moreover, the comparison between the successful titration group and the unsuccessful group, showed no difference in the central sleep apnea index. Nevertheless, patients with heart disease particularly patients with heart failure may need good clinical assessment before sending them for a split-night study.

This study has limitations that need to be addressed. Although we recruited consecutive patients with clinical suspicion of OSA, the majority of the studied patients had severe OSA as reflected by a high AHI. This could be related to the fact that our center is a tertiary referral center that receives sick patients. Therefore, our results cannot be extrapolated to patients with mild OSA. Future studies should explore the utility of split-night sleep study in mild OSA. Another limitation is the fact that the number of patients in the split-night protocol is more than that in the two-night sleep study protocol. Nevertheless, the number of patients in both groups is high enough to provide a good comparison.

Conclusion

Combining the diagnostic and CPAP titration parts of a sleep study into a single night (split-night protocol) has a high success rate particularly in patients with moderate to severe OSA. It is convenient to patients by cutting on the duration of admission, and to the SDC by reducing the waiting lists and decreasing the time needed for scoring PSGs. Moreover, acceptance of CPAP titration in the sleep laboratory and CPAP compliance after 10 months were comparable to the two-night sleep study protocol. Split-night protocol should be endorsed to all SDCs in Saudi Arabia to cut on the waiting list and to provide early diagnosis and treatment. Future studies should assess the success of CPAP titration at home and its impact on CPAP compliance among Saudi patients with OSA.

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