Original Research

Using Prediction Formulas for Continuous Positive Airway Pressure in Obstructive Sleep Apnea Syndrome

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Abstract

Background and Objective: Continuous positive airway pressure (CPAP) is a standard therapy for patients with moderate to severe obstructive sleep apnea (OSA). Increased demands for polysomnography (PSG) and CPAP titration have led to long waiting lists and high cost. CPAP prediction formulas derived from sleep and anthropometric parameters are used to set the initial CPAP level during CPAP titration. In the current study, we aimed to compare the pressure derived from prediction formulas with the pressure resulted from CPAP titration in a sample of Iranian patients.

Materials and Methods: In this cross-sectional study, 90 subjects with confirmed OSA in a full PSG who underwent CPAP titration in Baharloo Sleep Clinic, Tehran, Iran, during 2017, were enrolled. All of the participants had Respiratory Disturbance Index (RDI) ≥ 15 in their PSG test. Then, the optimal pressure obtained from manual CPAP titration was compared with the one calculated by different prediction formulas for each patient.

Results: The mean CPAP pressure from manual titration was greater than the pressures calculated by four prediction formulas. The difference between mean CPAP pressure obtained by manual titration and pressures calculated by Hoffstein, Lin, and Hukins formulas was statistically significant, whereas mean CPAP pressure obtained by manual titration was not statistically different from Loredo formula (11.7 ± 2.6 vs. 11.0 ± 2.3, $P = 0.110$).

Conclusion: Estimation of optimal therapeutic pressure for CPAP device using several prediction formulas is very similar to pressure found during manual titration study. These formulas can be used in our setting for estimation of optimal CPAP pressure to save time and cost.

Keywords: Apnea, Sleep; Continuous positive airway pressure; Polysomnography; Sleep

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Introduction

Obstructive sleep apnea (OSA) is a disorder characterized as a risk factor for a number of important chronic medical conditions and is responsible for poor quality of life (1). This disorder is accompanied by repetitive episodes of cessation of breathing (apneas), reduced breathing (hypopneas), or arousals associated with increased airway resistance and respiratory effort (respiratory effort-related arousal) (1-3). The prevalence of OSA syndrome (OSAS) in men and women is 4% and 2%, respectively (among middle-aged population) (4, 5). As age increases, the prevalence also rises and it is estimated around 28-67 percent for elderly men and 20-54 percent for elderly women (5, 6).

Sullivan et al. demonstrated that nasal continuous positive airway pressure (CPAP) could alleviate obstruction in upper airway of OSA (7). CPAP is the standard therapy for patients with moderate to severe OSA (8-11). Several studies showed that optimal levels of CPAP pressure reduced excessive daytime sleepiness (EDS) and improved health status compared with sub-therapeutic

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CPAP pressure levels (11-13). Current standard method for CPAP titration is an overnight manual pressure titration study by using polysomnography (PSG) (14). However, increased demands for PSG monitoring (diagnostic and CPAP titration) have led to long waiting lists and high cost (11, 15). Thus, several researchers have proposed other methods to determine optimal CPAP settings for patients with OSA such as a split-night study, auto-CPAP titration, and CPAP prediction formulas (16-19). Using auto-CPAP has largely solved this practical issue related to laboratory CPAP titration, but it should be avoided in some patients, such as those with congestive heart failure (CHF), substantial lung disease, or obesity hypoventilation syndrome (OHS) (20). Therefore, using a CPAP prediction formula remains useful. CPAP prediction formulas derived from sleep measurements and anthropometric parameters are used to set the initial CPAP level during CPAP titration and during initiation of CPAP therapy when titration is not used (21-23).

Several formulas for prediction of the observed optimal therapeutic CPAP (CPAPopt) (algorithm-based titration) have been applied. Miljeteig and Hoffstein reported the first predictive formula by using three independent factors including body mass index (BMI), neck circumference (NC), and apnea-hypopnea index (AHI) among Caucasians (14), but they did not consider race or lifestyle and factors known to affect the severity of OSA (14). However, this formula is not always adequate for establishment of optimal pressure (24, 25). In another study in Caucasian population, the prediction factors of the formula consisted of smoking (pack/year), BMI, and AHI (26). Akahoshi et al. predicted CPAPopt by a combination of cephalometric, anthropometric (BMI), and polysomnographic (AHI and mean oxyhemoglobin saturation) data (27). In Asians, Lin et al. developed a formula by using BMI and AHI as prediction factors in their study (28), whereas BMI, AHI, and desaturation index were the ones used by Chuang et al. in another Asian population (29). The aim of the current study was to compare the pressure derived from prediction formulas with the pressure resulted from CPAP titration in a sample of Iranian patients.

Materials and Methods

Participants: In this cross-sectional study, 90 patients with confirmed OSA in a full-night PSG who underwent CPAP titration study in Baharloo Sleep Clinic, Tehran, Iran, during 2017, were enrolled. Participants had Respiratory Disturbance Index (RDI) equal or greater than 15 in their overnight PSG test. Age, sex, height, weight, BMI, and NC of the subjects were recorded. Written informed consent was obtained from all of the patients**.** Patients with central sleep apnea (CSA), previous surgery for OSA, and the ones with chronic diseases and intolerance to CPAP in the night of study were excluded from this study.

Polysomnography (PSG): PSG consists of electroencephalography (EEG), electrooculography (EOG), electrocardiography (ECG), and electromyography (EMG) which is used for diagnosis of OSA and determination of the disease severity. Snoring, arterial blood oxygen saturation, respiratory airflow, and respiratory effort were monitored during night sleep. The apnea is defined when reduction in airflow is more than 90% from baseline for at least 10 seconds, and hypopnea is defined as a reduction in airflow more than 30% from baseline which takes at least 10 seconds with a $\geq$ 3% reduction in oxygen saturation or with arousal. Some of our parameters like RDI, mean O_2 saturation (mean SaO_2), and minimum O_2 saturation (nadir SaO_2) during overnight sleep were obtained from PSG test (30). Patients with moderate to severe OSA (RDI $\geq$ 15) were recruited in the current study.

CPAP titration: The participants, who were candidate for CPAP therapy and agreed to use the device, underwent a second night PSG test for in-laboratory manual titration. The optimal CPAP device pressure for treatment of OSA was determined by an expert sleep specialist and was documented for each patient according to American Academy of Sleep Medicine (AASM) guideline (30).

Prediction formulas: There are several clinical formulas which are used for predicting an effective CPAP including:

- Miljeteig and Hoffstein, 1993: Effective pressure = 0.13 (BMI) + 0.16 (NC) + 0.04 (RDI) - 5.12 (14)
- Loredo et al., 2007: Effective pressure = 30.8 + RDI (0.03) - nadir SaO_2 (0.05) - mean SaO_2 (0.2) (19)
- Lin et al., 2003: Effective pressure = 0.52 + 0.174 (BMI) + 0.042 (AHI) (28)

(In abovementioned formulas, we used RDI instead of AHI).

- Hukins, 2005: BMI < 30 = 8 cmH_2O, BMI

30-35 = 10 cmH_2O, BMI > 35 = 12 cmH_2O (31)

These formulas were used for predicting the effective pressure of CPAP device for each subject, then were compared with the pressure determined by CPAP titration study.

Statistical analysis: Descriptive statistics were presented as mean ± standard deviation (SD) and number and percentage. Mann–Whitney U test was performed for computing the difference between mean CPAP pressure obtained by manual titration and pressures calculated by each formula. Pearson correlation analysis was administered to measure the correlation between mean CPAP pressure obtained by manual titration and pressures calculated by each formula. P-value less than 0.050 was considered statistically significant. Statistical analysis was performed by SPSS software (version 22, IBM Corporation, Armonk, NY, USA).

Results

The mean age of the participants of this study was 50.9 ± 12.4 years. Of 90 subjects, 65 patients (72.2%) were men. Demographic and polysomnographic characteristics of the participants are shown in table 1. Study participants had a mean BMI of 30.9 ± 5.4 kg/m^2 and the mean RDI of 58.1 ± 28.3 (range: 16.9-134) in line with moderate to severe OSA.

Table 1. Demographic and polysomnographic characteristics of the patients

Variable	Mean ± SD
Age (year)	50.9 ± 12.4
BMI (kg/m^2)	30.9 ± 5.4
NC (cm)	41.0 ± 3.8
RDI (/h)	58.1 ± 28.3
Mean Sao_2 (%)	88.9 ± 6.9
Lowest Sao_2 (%)	73.5 ± 12.3

BMI: Body mass index; NC: Neck circumference; RDI: Respiratory disturbance index; Sao_2: Oxyhemoglobin saturation

Pearson correlation analysis between CPAP pressure from manual titration and formulas showed that pressure calculated by Miljeteig and Hoffstein (14), Loredo et al. (19), and Lin et al. (28) formulas was significantly correlated with CPAP pressure obtained by manual titration; however, correlation between pressure calculated by Hukins formula (31) and CPAP pressure obtained by manual titration was not significant (Table 2).

Table 2. Correlation between continuous positive airway pressure (CPAP) obtained from manual titration and four prediction formulas

CPAP titration with	Correlation	P-value
Miljeteig and Hoffstein formula (14)	0.279	0.010
Loredo et al. formula (19)	0.302	0.004
Lin et al. formula (28)	0.234	0.027
Hukins formula (31)	0.040	0.710

CPAP: Continuous positive airway pressure

The mean CPAP pressure obtained from manual titration was greater than pressures calculated by four prediction formulas (Table 3). The difference between mean CPAP pressure obtained by manual titration and pressures calculated by Miljeteig and Hoffstein (14), Lin et al. (28), and Hukins (31) formulas was statistically significant, whereas mean CPAP pressure obtained by manual titration was not statistically different from Loredo et al. (19) formula (11.7 ± 2.6 vs. 11.0 ± 2.3, P = 0.110).

Discussion

Manual CPAP titration is considered as the method of choice for titration, but because of its long waiting lists, high cost, inappropriate patient education, discomfort in patients, and other limitations, there are good reasons to use prediction formulas.

Table 3. Continuous positive airway pressure (CPAP) resulted from manual titration and four prediction formulas

	Mean ± SD
Manual CPAP titration pressure	11.7 ± 2.6
Miljeteig and Hoffstein formula (14)	7.7 ± 1.7
Effective pressure = 0.13 (BMI) + 0.16 (NC) + 0.04 (RDI) – 5.12	
Loredo et al. formula (19)	11.0 ± 2.3
Effective pressure = 30.8 + RDI (0.03) - nadir SaO_2 (0.05) - mean SaO_2	
Lin et al. formula (28)	8.3 ± 1.6
Effective pressure = 0.52 + 0.174 (BMI) + 0.042 (AHI)	
Hukins formula (31)	9.4 ± 1.5
Effective pressure = BMI < 30 = 8 cmH_2O, BMI 30-35 = 10 cmH_2O, BMI > 35 = 12 cmH_2O	

CPAP: Continuous positive airway pressure; SD: Standard deviation; BMI: Body mass index; RDI: Respiratory disturbance index; Sao_2: Oxyhemoglobin saturation; AHI: Apnea-hypopnea index

In the current study, the comparison between the pressure calculated by four prediction formulas and the pressure resulted from manual CPAP titration in Iranian sleep clinic patients, was evaluated.

65 participants of this study were men (72.2%), similar to OSA ratio (8:1) in the laboratory sample; thus, sex did not affect the calculations (32).

In our study, the mean BMI was 30.9 ± 5.4 kg/m², while in the studies of Asian and non-Asian populations, the means of BMI were 25.1-28.4 kg/m² and 30.9-40.6 kg/m², respectively (33).

In recent years, several alternative methods to PSG for CPAP titration have been designed, for example, split full-night sleep studies (34), CPAP titration in a nap setting (35), and the use of formulas. In the literature, four CPAP prediction formulas for therapeutic purposes are introduced. Miljeteig and Hoffstein determined CPAP predictive formula by measurements of BMI, NC, and RDI (14). Lin et al. found measurements of BMI and AHI (28). In Loredo et al. prediction formula for CPAP, BMI, RDI, and SaO_2 were significant predictors of CPAP pressure (19), and Hukins used only BMI (31).

In our study, the mean CPAP pressure from manual titration was greater than pressures calculated by four prediction formulas as shown in previous studies, which can be due to air leaks from different sources like mask leaks and mouth breathing. Our findings were closer to pressure calculated by Loredo et al. (19) formula (P = 0.010).

Respiratory events including apnea/hypopnea and snoring are the main parameters for manual adjustment of pressure while these formulas did not consider snoring.

From a literature review, facial anatomy differences exist between Iranian and American, Australian, and Taiwanese individuals; thus, race and ethnicity may affect CPAP pressure. Asians have more severe OSAS but lower BMI than Caucasians; craniofacial abnormalities had a strong correlation with OSAS in patients with lower BMI (36-38). Akahoshi et al. found BMI, AHI, mean SaO_2, and cephalometric parameters as predictors of optimal CPAP (27). Therefore, it is useful to establish a formula to predict CPAP by using cephalometric parameters, BMI, and polysomnographic characteristics based on Iranian sample in future investigations.

Conclusion

We can use prediction formulas for CPAP titration as a guide for initiation of therapy for saving time and cost.

Conflict of Interests

Authors have no conflict of interests.

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