Prediction of Optimal CPAP Pressure and Validation of an Equation for Asian Patients With Obstructive Sleep Apnea

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BACKGROUND: The Hoffstein formula is the most widely used equation to predict optimal CPAP pressure in patients with obstructive sleep apnea, but it is based on data from white patients. The purpose of this study was to develop an equation for optimal CPAP based on data from Asian patients, and to compare this new formula with the Hoffstein formula. METHODS: We retrospectively reviewed the records of 356 Korean subjects with obstructive sleep apnea who had undergone successful CPAP titration, and randomly divided them into 2 groups, with 178 subjects per group. In group 1 we used stepwise multiple linear regression analysis to develop a predictive equation for optimal CPAP. Then we compared our equation with the Hoffstein equation in group 2. RESULTS: A predictive equation was: predicted pressure (cm H_2O) = 6.656 + 0.156 × (body mass index [kg/m^2]) – 0.071 × (minimal S_{pO_2} [%]) + 0.041 × (respiratory disturbance index) + 0.094 × (score of Epworth Sleepiness Scale). This equation accounted for 38.9% of the total variance ($P < .001$). Proportions of optimal estimation of CPAP pressure were 38.8% and 36.5% in this equation and the Hoffstein equation, respectively. The Hoffstein formula significantly underestimated CPAP, compared with our formula. CONCLUSIONS: Although our equation was somewhat better to predict optimal CPAP level in Asian subjects than the Hoffstein equation, the CPAP prediction equation did not accurately predict the prescribed CPAP level. Therefore, the usefulness of the CPAP prediction formula is limited in some clinical settings. *Key words: CPAP; obstructive sleep apnea; CPAP titration; race.* [Respir Care 2013;58(5):810–815. © 2013 Daedalus Enterprises]

Introduction

The use of CPAP as a treatment for obstructive sleep apnea (OSA) was first proposed in 1981.[1] CPAP is now well known to reduce the symptoms and cardiovascular complications associated with OSA.[2,3] A laboratory CPAP titration is typically performed to determine the pressure required to eliminate apnea,[4] but this procedure is time-consuming and often associated with a delayed CPAP initiation. Thus, several researchers have proposed other methods to determine optimal CPAP settings for OSA patients, such as a split-night study,[5] auto-CPAP titration,[6] and CPAP prediction formulas.[7-13] 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, substantial lung disease, or obesity hypoventilation syndrome.[14] Therefore, using a CPAP prediction formula remains useful in clinical practice, especially in these specific populations.

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. Hoffstein et al[7] developed and validated a formula to predict optimal CPAP settings.[15,16] However, this formula is not always adequate for establishment of optimal pressure.[17] In particular, the Hoffstein equation considers body mass index (BMI), neck circumference, and apnea-hypopnea index (AHI), but does not consider race or lifestyle, factors known to affect the severity of OSA.[18] Asians with lesser

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degrees of obesity are at risk for a more severe degree of illness, compared with whites. In addition, craniofacial factors are important determinants of OSA risk.[19-21] Thus, a different formula may be needed to determine optimal CPAP level for Asian OSA patients. The purpose of this study was to develop an equation for optimal CPAP pressure in Asian patients, and to compare this new equation with the original Hoffstein equation.

QUICK LOOK

Current knowledge

The Hoffstein formula, which is often used to predict the optimal CPAP pressure in patients with obstructive sleep apnea, is based on data from white patients, and the formula's applicability to people of other ethnicities is unclear.

What this paper contributes to our knowledge

The Hoffstein equation did not accurately predict the optimal CPAP in Korean patients. A new CPAP prediction equation based on data from the Korean subjects was more accurate, but use of the equation is limited in that it did not accurately predict the prescribed CPAP level.

Methods

Subjects

We retrospectively studied subjects with OSA who were at least 18 years old and had undergone CPAP titration at the Asan Medical Center sleep laboratory, from April 2008 to March 2011. All subjects had OSA, defined as an AHI > 5 events/h, which was diagnosed at an initial overnight diagnostic polysomnography. A second polysomnographic titration study to determine the optimal CPAP level was performed within 2 months of the first polysomnography. We excluded patients with acute stroke or other severe medical problems, or who were taking sleeping drugs. During the enrollment period, 438 patients with OSA had undergone CPAP titration in our laboratory. We enrolled only subjects with optimal and good titration. Optimal titration was defined as reduction of Respiratory Disturbance Index (RDI) < 5 for at least a 15-min duration, including supine REM sleep at the selected pressure that is not continually interrupted by spontaneous arousals or awakenings. And good titration was defined as reduction of RDI by ≤ 10 events/h, or by 50% if the baseline RDI was < 15 events/h, and should include supine REM sleep.[4] We excluded 32 patients who failed CPAP titration and 40 patients who had unsuccessful results, which were defined as RDI of 10 events/h or more or no supine REM sleep at the selected pressure.[4] We recorded Epworth Sleepiness Scale (ESS) score and anthropometric variables, including age, height, weight, and neck circumference. The study was reviewed and approved by the institutional review board of the Asan Medical Center.

Polysomnography

Polysomnography was performed according to established standards[22,23] (RemLogic 2.0, Embla Systems, Thornton, Colorado), and included electroencephalography (C3-A2, C4-A1, F3-A2, F4-A1, O1-A2, O2-A1), electrooculography (ROC-A1, LOC-A2), electromyography, electrocardiography (modified V2 lead), S_{pO_2}, and a microphone to detect snoring. Electromyography was recorded on the chin and both anterior tibial muscles. Air flow assessment was performed with an oronasal thermistor and a nasal pressure transducer. Thoracoabdominal movement assessment was performed by respiratory inductance plethysmography. Snoring was detected by a microphone.

Sleep and associated events were scored according to the American Academy of Sleep Medicine manual (2007).[23] Sleep stages were identified for each 30-second epoch by a well trained registered polysomnographic technologist. An apnea was defined as a drop in the peak thermal sensor excursion by at least 90% from baseline for at least 10 seconds. A hypopnea was defined as a nasal pressure signal drop of at least 30% from baseline for at least 10 seconds with at least 4% reduction of S_{pO_2} from the pre-event baseline. A respiratory-effort-related arousal was defined as a sequence of breaths lasting at least 10 seconds, characterized by flattening of the nasal pressure waveform and leading to arousal from sleep, when the sequence of breaths did not meet criteria for apnea or hypopnea. The AHI was defined as the ratio of apneas and hypopneas per hour, and the RDI was calculated as the average number of episodes of apnea, hypopnea, plus respiratory-effort-related arousal per hour. Total sleep time was defined as total minutes in purely N1, N2, N3, and REM sleep.

CPAP Titration

For CPAP titration a standard polysomnography, as described earlier, was performed by a well trained registered polysomnographic technologist, using the REMstar Plus M series w/C-flex (Respironics, Murrysville, Pennsylvania). CPAP was manually titrated until the lowest effective CPAP level was reached based on clinical guidelines.[4] The starting CPAP was 4 cm H_2O, and the pressure was increased by at least 1 cm H_2O within an interval of 5 min or more. CPAP was increased if there were 2 obstructive apneas, 3 hypopneas, or 5 respiratory-effort-related arousals, or at least 3 min of loud or unambiguous snoring. The titrated CPAP level was defined as the lowest effective pressure.

Statistical Analysis

We randomly divided our 356 subjects into 2 groups (each with 178 persons) and chi-square test or independent *t* tests were used to assess differences of variables between groups. These variables included 4 anthropometric parameters (age, sex, BMI, neck circumference), 12 polysomnographic parameters (sleep latency, sleep efficiency, sleep time [N1, N2, N3, REM, and total]), AHI, RDI, minimal S_{pO_2}, mean S_{pO_2}, and ESS. In group 1 we used the Pearson correlation test or an independent *t* test to evaluate the association of these variables with titrated CPAP level. Variables with *P* values $< .05$ in the univariate analysis were entered into a stepwise multiple linear regression analysis to identify independent predictive variables and to develop a predictive formula for optimal CPAP.

In group 2 we compared the regression equation derived from group 1 with the Hoffstein formula by use of Pearson correlation and paired *t* test. Prediction was classified as optimal estimation (difference of measured pressure and predicted pressure of 1 cm H_2O or less), underestimation ($>$ 1 cm H_2O low), or overestimation ($>$ 1 cm H_2O high). We also examined frequency histograms (pressure of CPAP titration – pressure of prediction) to determine how well predicted pressure approximated titrated pressure in individual subjects. Results are presented as means ± standard deviations. Statistics software (SPSS 18, SPSS, Chicago, Illinois) was used for the statistical analysis, and a *P* value $< .05$ was considered significant.

Results

We retrospectively evaluated 356 subjects (313 men, 43 women). The mean BMI was 26.5 ± 3.8 kg/m², mean RDI was 44.7 ± 19.1 events/h, and mean AHI was 39.2 ± 24.8 events/h, consistent with severe OSA. Subjects were randomly divided into 2 groups, with 178 subjects per group. There were no significant differences between the 2 groups in age, sex proportions, neck circumference, BMI, ESS, and polysomnographic data, including AHI and RDI (Table 1).

In group 1, univariate analysis indicated that the measured CPAP pressure was significantly associated with BMI, neck circumference, ESS, N1, N2, total sleep time, AHI, RDI, minimal S_{pO_2}, and mean S_{pO_2} (Table 2). Stepwise multiple regression analysis indicated that BMI, minimal S_{pO_2}, RDI, and ESS were independent predictors of the measured CPAP pressure (Table 3). We used these parameters to develop an equation to predict optimal CPAP pressure (P_{pred}):

Table 1. Polysomnography Data

	Group 1	Group 2	*P*
Male/female, no.	153/25	160/18	.47
Age, y	51.7 ± 10.6	51.7 ± 11.2	.83
BMI, kg/m²	26.3 ± 3.6	26.6 ± 4.0	.23
Neck circumference, cm	40.0 ± 3.2	40.3 ± 3.5	.56
Epworth Sleepiness Scale score	10.4 ± 5.1	10.5 ± 5.1	.93
Sleep latency, min	7.5 ± 16.4	8.6 ± 26.0	.53
Sleep efficiency, %	90.4 ± 22.7	88.6 ± 10.6	.55
Sleep state, %			
N1	33.5 ± 15.2	34.4 ± 17.5	.12
N2	42.0 ± 12.4	40.8 ± 14.0	.13
N3	7.9 ± 8.3	7.9 ± 7.8	.94
REM	16.9 ± 7.8	16.9 ± 7.2	.69
Total sleep time, min	351.8 ± 50.6	359.3 ± 53.3	.57
AHI, events/h	40.1 ± 29.0	38.5 ± 19.9	.25
RDI, events/h	45.1 ± 19.4	44.3 ± 18.8	.62
Minimal O_2 saturation, %	78.0 ± 9.7	78.5 ± 7.9	.09
Mean O_2 saturation, %	93.8 ± 2.7	94.1 ± 2.6	.80
CPAP titrated pressure, cm H_2O	8.1 ± 2.6	7.8 ± 2.4	.16

Values are mean ± SD unless otherwise indicated.
BMI = body mass index
REM = rapid eye movement
AHI = Apnea-Hypopnea Index
RDI = Respiratory Disturbance Index

$$P_{pred} = 6.656 + 0.156 \times BMI - 0.071 \times \text{minimal } S_{pO_2} + 0.041 \times RDI + 0.094 \times ESS$$

This equation accounted for 38.9% of the total variance ($R^2 = 0.39$, $P < .001$).

Next, we compared the pressure predicted by our formula (P_{pred}) and the Hoffstein formula (P_{Hoff}) in group 2. The results indicate that P_{pred} was positively correlated with the titrated pressure (Fig. 1, $r = 0.49$, $P < .001$) and that P_{Hoff} was also positively correlated with the titrated pressure ($r = 0.50$, $P < .001$).

Our formula provided an optimal estimation of CPAP pressure for 69 subjects (38.8%) and the Hoffstein formula provided an optimal estimation of CPAP pressure in 65 subjects (36.5%) (Table 4). The rate of underestimation was greater for the Hoffstein formula (51.7%, 92 subjects) than for our formula (25.8%, 46 subjects), and the rate of overestimation was greater for our formula (35.4%, 63 subjects) than for the Hoffstein formula (11.8%, 21 subjects) (see Fig. 1 and 2).

Discussion

We examined a large group of OSA subjects who had undergone CPAP titration, developed a new CPAP pres-

Table 2. Relationship Between Titrated CPAP Pressure and Anthropometric and Polysomnographic Data in Group 1

	Correlation Coefficient	*P*
Sex		.47*
Age	–0.08	.31
BMI	0.40	< .001
Neck circumference	0.38	< .001
Epworth Sleepiness Scale score	0.19	.01
Sleep latency	0.03	.70
Sleep efficiency	0.01	.97
Sleep state		
N1	0.36	< .001
N2	–0.29	< .001
N3	–0.01	.85
REM	0.04	.60
Total sleep time	0.17	.02
AHI	0.35	< .001
RDI	0.48	< .001
Minimal O_2 saturation	–0.47	< .001
Mean O_2 saturation	–0.50	< .001

* By independent analysis; other *P* values via Pearson correlation test.
BMI = body mass index,
REM = rapid eye movement
AHI = Apnea-Hypopnea Index
RDI = Respiratory Disturbance Index

Table 3. Multiple Linear Regression Analysis of Variables Independently Associated With Titrated CPAP Pressure

	$\beta \pm$ SE	*P*
Body mass index	0.16 ± 0.05	.001
Minimum S_{pO_2}	–0.07 ± 0.02	< .001
Respiratory Disturbance Index	0.04 ± 0.01	< .001
Epworth Sleepiness Scale	0.09 ± 0.03	.003

sure prediction equation for Asian patients, and then compared our formula with the Hoffstein formula in a separate validation group. The Hoffstein formula is the most widely used equation for prediction of CPAP pressure, but was developed without considering data from Asian OSA patients. Based on our regression formula, CPAP pressure level was determined by BMI, minimal S_{pO_2}, RDI, and sleepiness assessed by ESS. This equation accounted for 38.9% of the total variance. A frequency histogram of differences between titrated and predicted pressure showed a normal distribution in our equation, but showed a skewed distribution in the Hoffstein equation. It meant that the Hoffstein equation tended to underestimate CPAP level for Asian patients, compared with our equation.

Our study showed that degree of daytime sleepiness assessed by ESS was significantly and independently related to titrated CPAP pressure. Multivariate regression analysis indicated that ESS was related to titrated optimal

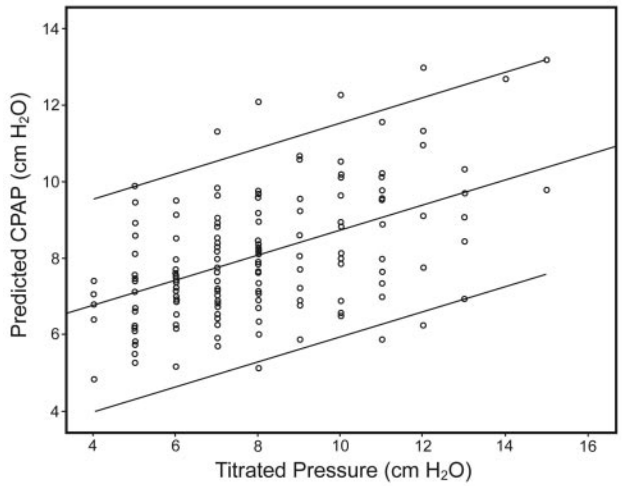

Fig. 1. Correlation of predicted CPAP pressure from our formula with titrated pressure. The upper and lower lines indicate 95% confidence intervals.

Table 4. Estimation of Optimal CPAP Pressure by the Equation in This Paper and the Hoffstein Equation

	Underestimation, no. (%)*	Optimal Estimation, no. (%)†	Overestimation, no. (%)‡
Our equation	46 (25.8)	69 (38.8)	63 (35.4)
Hoffstein equation	92 (51.7)	65 (36.5)	21 (11.8)

* Underestimation: 1 cm H_2O < pressure of CPAP titration − pressure of prediction.
† Optimal estimation: –1 cm H_2O ≤ pressure of CPAP titration − pressure of prediction ≤ 1 cm H_2O.
‡ Overestimation: –1 cm H_2O > pressure of CPAP titration − pressure of prediction.

pressure ($\beta = 0.10 \pm -0.031$, $P = .003$). The presence of the variable ESS in our equation differentiates our CPAP formula from all other previously proposed CPAP formulas.[7-13] Most investigators did not evaluate a variable related to daytime sleepiness, such as ESS, to develop their CPAP predictive formula. Stradling et al[11] included ESS in variables evaluated for their formula. However, ESS was not a significant predictive factor and so was not included in their predictive formula. It was probably because they included only OSA patients with elevated ESS (≥ 10).

The effect of race on the determination of optimal CPAP pressure should be taken into consideration. In this study the Hoffstein equation tended to underestimate optimal CPAP level for our Asian subjects, compared with our equation. In general, Asian patients are less obese than Western patients, which was also supported by our data. The mean BMI of our subjects (26.5 ± 3.8 kg/m^2) was much lower, comparing to that of the Hoffstein study (34 ± 8 kg/m^2). Also, craniofacial structures contribute differentially to OSA in Asian and white patients. Asian

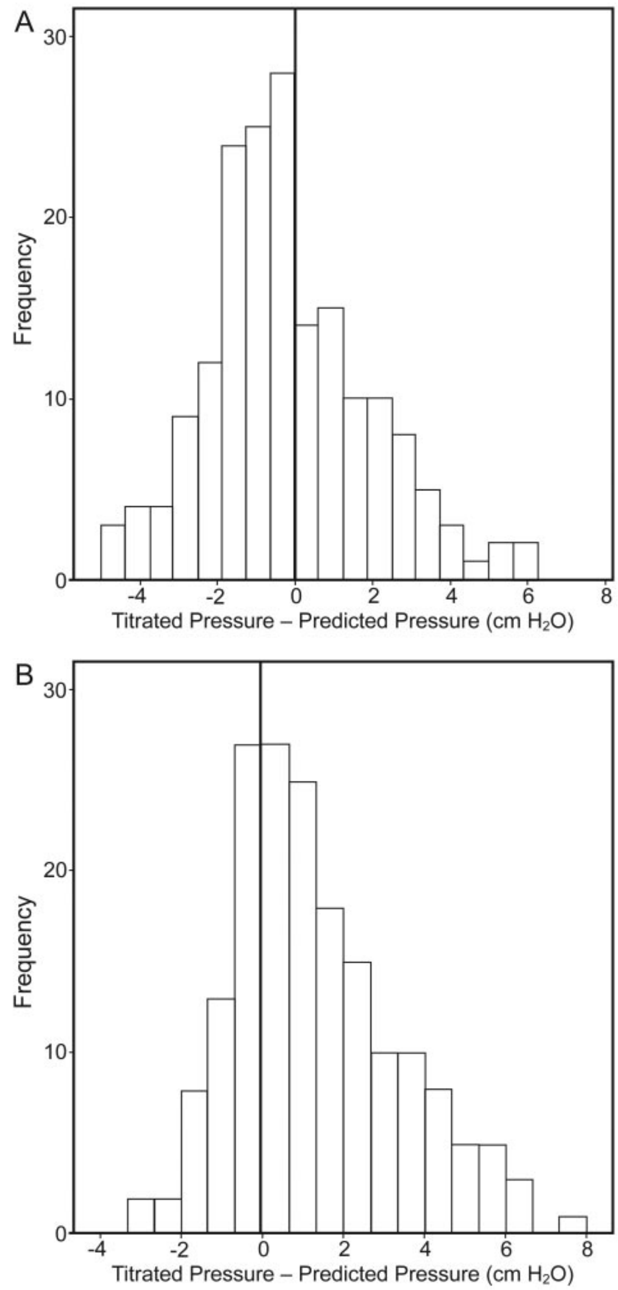

Fig. 2. Frequency histogram of (titrated CPAP pressure – pressure of prediction). A: Our formula. B: the Hoffstein formula.

patients exhibited more craniofacial bony restriction,[13,24] which was characterized by shorter anterior cranial base and narrower cranial base flexure than whites, when matched for BMI and age.[24,25] In addition, the coefficients of determination in CPAP predictive formulae seem to be low (0.39–0.47) in studies of Asians,[8,9,13] including our subjects, and to be relatively high (0.67) in studies of whites.[12,15] This suggests that variables not traditionally considered when developing CPAP pressure prediction formulas may have greater influence in Asian patients than in other populations.

In the literature review we found 3 previous studies to develop CPAP predictive formulae in the Asian population. Equations from 2 studies performed in Taiwan (n = 121)[8] and Korea (n = 202)[9] were derived from anthropometric and polysomnographic data similar to our study. BMI and AHI were identified as independent predictors of optimal CPAP. But their equations were not validated. In contrast, we validated our formula in a separate validation group and compared it with the Hoffstein formula. In addition, daytime sleepiness assessed by ESS was identified as an independent predictor and so was included in our equation. In another Japanese study,[13] a predictive equation was derived from anthropometric, polysomnographic, and cephalometric data of 170 Japanese OSA subjects, and the authors validated their equation in another 110 subjects. They found AHI, BMI, mean S_{pO_2}, and a cephalometric parameter (the angle between a line from point B to the menton and a line from menton to the hyoid bone) as independent predictors of optimal CPAP. This equation accounted for 47% of the variance in optimal pressure, which was somewhat higher than that of our equation (38.9%). This finding suggested that optimal CPAP level was more accurately predicted by combining a cephalometric parameter with BMI and polysomnographic data.

There is evidence of sex differences in the clinical presentation and polysomnographic findings of OSA. Males experience OSA at 2 to 3 times the rate of females,[26] present with OSA at a younger age,[27] and have a higher AHI[28,29] than females. In contrast, females are likely to be more obese, with a smaller neck circumference than males.[30] These sex differences may be expected to influence optimal CPAP pressure in patients with OSA. Schiza et al[31] evaluated sex effect on a CPAP predicting equation and found that sex was a statistically significant factor to predict CPAP pressure by linear regression. So they separately developed prediction formulae for each male and female. Our study population included a majority of males, which was similar to male predominance in OSA, by a ratio of 8:1 in the laboratory sample.[32] Therefore, our equation was developed and validated in a mostly male population, and did not take sex effect into account.

Our formula provided an optimal estimation of CPAP pressure for a low proportion of subjects (38.8%), which was similar when the Hoffstein formula was applied to our study population. Therefore, a predictive equation is not a sufficient substitute for the manual CPAP titration. However, the use of a CPAP prediction formula may improve manual CPAP titration success by increasing the starting pressure of the titration, especially during split-night studies. Rowley et al[30] reported that the use of a CPAP prediction formula increased the percentage of successful studies from 50% to 68%, for which the AHI at the final level tested was ≤ 50% of baseline and ≤ 10 events/h.

Conclusions

In summary, a CPAP prediction equation for Asian OSA subjects was developed and validated in this study. Although our equation was somewhat better to predict optimal CPAP level in Asian subjects than the Hoffstein equation, the CPAP prediction equation did not accurately predict the prescribed CPAP level. Therefore, its usefulness is limited in some clinical settings.

REFERENCES

1. Sullivan CE, Issa FG, Berthon-Jones M, Eves L. Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. Lancet 1981;1(8225):862-865.
2. Ballester E, Badia JR, Hernandez L, Carrasco E, de Pablo J, Fornas C, et al. Evidence of the effectiveness of continuous positive airway pressure in the treatment of sleep apnea/hypopnea syndrome. Am J Respir Crit Care Med 1999;159(2):495-501.
3. Yun CH, Jung KH, Chu K, Kim SH, Ji KH, Park HK, et al. Increased circulating endothelial microparticles and carotid atherosclerosis in obstructive sleep apnea. J Clin Neurol 2010;6(2):89-98.
4. Kushida CA, Chediak A, Berry RB, Brown LK, Gozal D, Iber C, et al. Clinical guidelines for the manual titration of positive airway pressure in patients with obstructive sleep apnea. J Clin Sleep Med 2008;4(2):157-171.
5. McArdle N, Grove A, Devereux G, Mackay-Brown L, Mackay T, Douglas NJ. Split-night versus full-night studies for sleep apnoea/hypopnoea syndrome. Eur Respir J 2000;15(4):670-675.
6. Series F. Accuracy of an unattended home CPAP titration in the treatment of obstructive sleep apnea. Am J Respir Crit Care Med 2000;162(1):94-97.
7. Miljeteig H, Hoffstein V. Determinants of continuous positive airway pressure level for treatment of obstructive sleep apnea. Am Rev Respir Dis 1993;147(6 Pt 1):1526-1530.
8. Lin IF, Chuang ML, Liao YF, Chen NH, Li HY. Predicting effective continuous positive airway pressure in Taiwanese patients with obstructive sleep apnea syndrome. J Formos Med Assoc 2003;102(4):215-221.
9. Choi JH, Kim EJ, Kim KW, Choi J, Kwon SY, Lee HM, et al. Optimal continuous positive airway pressure level in korean patients with obstructive sleep apnea syndrome. Clin Exp Otorhinolaryngol 2010;3(4):207-211.
10. Sforza E, Petiau C, Weiss T, Thibault A, Krieger J. Pharyngeal critical pressure in patients with obstructive sleep apnea syndrome. Clinical implications. Am J Respir Crit Care Med 1999;159(1):149-157.
11. Stradling JR, Hardinge M, Paxton J, Smith DM. Relative accuracy of algorithm-based prescription of nasal CPAP in OSA. Respir Med 2004;98(2):152-154.
12. Loredo JS, Berry C, Nelesen RA, Dimsdale JE. Prediction of continuous positive airway pressure in obstructive sleep apnea. Sleep Breath 2007;11(1):45-51.
13. Akahoshi T, Akashiba T, Kawahara S, Uematsu A, Nagaoka K, Kiyofuji K, et al. Predicting optimal continuous positive airway pressure in Japanese patients with obstructive sleep apnoea syndrome. Respirology 2009;14(2):245-250.
14. Morgenthaler TI, Aurora RN, Brown T, Zak R, Alessi C, Boehlecke B, et al. Practice parameters for the use of autotitrating continuous positive airway pressure devices for titrating pressures and treating adult patients with obstructive sleep apnea syndrome: an update for 2007. An American Academy of Sleep Medicine report. Sleep 2008;31(1):141-147.
15. Hoffstein V, Mateika S. Predicting nasal continuous positive airway pressure. Am J Respir Crit Care Med 1994;150(2):486-488.
16. Oliver Z, Hoffstein V. Predicting effective continuous positive airway pressure. Chest 2000;117(4):1061-1064.
17. Gokcebay N, Iqbal S, Yang K, Zebrak A, Hirshkowitz M. Accuracy of CPAP predicted from anthropometric and polysomnographic indices. Sleep 1996;19(7):600-601.
18. Villaneuva AT, Buchanan PR, Yee BJ, Grunstein RR. Ethnicity and obstructive sleep apnoea. Sleep Med Rev 2005;9(6):419-436.
19. Wong ML, Sandham A, Ang PK, Wong DC, Tan WC, Huggare J. Craniofacial morphology, head posture, and nasal respiratory resistance in obstructive sleep apnoea: an inter-ethnic comparison. Eur J Orthod 2005;27(1):91-97.
20. Liu Y, Lowe AA, Zeng X, Fu M, Fleetham JA. Cephalometric comparisons between Chinese and Caucasian patients with obstructive sleep apnea. Am J Orthod Dentofacial Orthop 2000;117(4):479-485.
21. Lam B, Ooi CG, Peh WC, Lauder I, Tsang KW, Lam WK, et al. Computed tomographic evaluation of the role of craniofacial and upper airway morphology in obstructive sleep apnea in Chinese. Respir Med 2004;98(4):301-307.
22. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The Report of an American Academy of Sleep Medicine Task Force. Sleep 1999;22(5):667-689.
23. Iber C, Ancoli-Israel S, Chesson AL Jr, Quan SF; American Academy of Sleep Medicine. The AASM manual for the scoring of sleep and associated events. Rules, terminology and technical specifications. Westchester, IL: American Academy of Sleep Medicine; 2007.
24. Lee RW, Vasudavan S, Hui DS, Prvan T, Petocz P, Darendeliler MA, et al. Differences in craniofacial structures and obesity in Caucasian and Chinese patients with obstructive sleep apnea. Sleep 2010;33(8):1075-1080.
25. Li KK, Kushida C, Powell NB, Riley RW, Guilleminault C. Obstructive sleep apnea syndrome: a comparison between Far-East Asian and white men. Laryngoscope 2000;110(10 Pt 1):1689-1693.
26. Young T, Palta M, Dempsey J, Skatrud J, Weber S, Badr S. The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 1993;328(17):1230-1235.
27. Young T, Hutton R, Finn L, Badr S, Palta M. The gender bias in sleep apnea diagnosis. Are women missed because they have different symptoms? Arch Intern Med 1996;156(21):2445-2451.
28. Pillar G, Lavie P. Psychiatric symptoms in sleep apnea syndrome: effects of gender and respiratory disturbance index. Chest 1998;114(3):697-703.
29. Shepertycky MR, Banno K, Kryger MH. Differences between men and women in the clinical presentation of patients diagnosed with obstructive sleep apnea syndrome. Sleep 2005;28(3):309-314.
30. Rowley JA, Aboussouan LS, Badr MS. The use of clinical prediction formulas in the evaluation of obstructive sleep apnea. Sleep 2000;23(7):929-938.
31. Schiza SE, Bouloukaki I, Mermigkis C, Panagou P, Tzanakis N, Moniaki V, et al. Utility of formulas predicting the optimal nasal continuous positive airway pressure in a Greek population. Sleep Breath 2011;15(3):417-423.
32. Redline S, Kump K, Tishler PV, Browner I, Ferrette V. Gender differences in sleep disordered breathing in a community-based sample. Am J Respir Crit Care Med 1994;149(3 Pt 1):722-726.