

Comparison Optimal Pressure between Automatic Titrating and Predicting Continuous Positive Airway Pressure

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Background: Optimal continuous positive airway pressure (CPAP) level reduced excessive daytime sleepiness and improved healthy status compared with subtherapeutic CPAP pressure for patients with obstructive sleep apnea syndromes. To date there have been no studies comparing the differences between the automatic CPAP titrating pressure levels (ACPAPL) and the predicting CPAP pressure levels (PCPAPL). In this study, we compared the differences between these two pressures and investigated the factors effecting ACPAPL and PCPAPL.

Methods: A retrospective study included 49 patients who were diagnosed with obstructive sleep apnea syndromes and prescribed CPAP therapy by physicians. ACPAPL as determined using automated CPAP was defined as 95th percentiles pressure. The PCPAPL was calculated according to body mass index (BMI), neck circumference (NC), and apnea/hypopnea index (AHI) formula. The paired t-test was used to compare ACPAPL and PCPAPL. The correlation analysis was used to determine the relationship between ACPAPL with maximum leak values, median leak values, 95th percentile leak value, BMI, NC, and AHI.

Results: The mean ACPAPL (10.4 ± 1.8 cmH₂O) was significantly higher than the mean PCPAPL (7.82 ± 1.51 cmH₂O). The differences in the results were statistically significant ($p < 0.001$). There were 98% of patients had air leaks. The ACPAPL had good correlation with maximum leaks ($r = 0.44$, 95% CI 0.18 to 0.64), median leak values ($r = 0.46$, 95% CI 0.20 to 0.66), and 95th percentile leak values ($r = 0.30$, 95% CI 0.02 to 0.54), however, the correlations with BMI ($r = 0.05$, 95% CI -0.23 to 0.33), NC ($r = -0.18$, 95% CI -0.44 to 0.10), and AHI ($r = 0.23$, 95% CI -0.06 to 0.48) were poor.

Conclusion: The ACPAPL were higher than PCPAPL. The pressure differences between ACPAPL and PCPAPL were wide. Air leaks were common during the automatic CPAP titration. Leak value was one of the important factors that effected ACPAPL.

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Key words: continuous positive airway pressure, obstructive sleep apnea, automated CPAP titration, predicting CPAP, leak.

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Continuous positive airway pressure (CPAP) is the standard of treatment for patient with obstructive sleep apnea syndromes.^(1,2) Some researchers showed that optimal CPAP pressure levels reduced excessive daytime sleepiness and improved self-reported health status compared with subtherapeutic CPAP pressure levels.^(3,4) Current standard practice for CPAP titration is overnight manually pressure titration under polysomnography (PSG) in a sleep laboratory.⁽⁵⁾ During titration, different pressures are applied and the efficacy of each for maintaining airway patency is assessed.⁽⁶⁾ However, increased demands for PSG monitoring for both diagnostic and CPAP titration purposes are creating long waiting lists and a high cost. Automated CPAP was engineered to automatically provide a positive pressure to the upper airway. According to previous reports, there were no significant differences between the optimal CPAP levels achieved with full PSG or automatic CPAP titration⁽⁷⁻⁹⁾ and the compliance of patients between the fixed-level CPAP and automated CPAP were also not statistically different.⁽¹⁰⁻¹⁴⁾

On the other hand, published reports claimed that optimal CPAP can be predicted from formula using body mass index (BMI) and baseline apnea/hypopnea index (AHI).⁽¹⁵⁾ The differences between predicting CPAP levels (PCPAPL) and optimal CPAP pressure titrated using the manual technique revealed that 83% patients were within ± 2 cmH₂O; and 95% were within ± 3 cmH₂O.^(16,17) In our sleep laboratory, most of the patients received automatic CPAP titrating, in order to reduce technicians work load and allow them to attend titration of more patients. From clinical observation, automatic CPAP titrating pressure levels (ACPAPL) are higher than either manually titrating pressure or PCPAPL. Ideally, three values need to be compared directly. However, manually titrating the pressure was not available in our study. The PCPAPL and ACPAPL were well documented and they had been separately compared with manually titrating pressure in previous reports.⁽⁷⁻¹⁷⁾ Therefore, the aim of this study was to directly compare the optimal CPAP pressure derived from a previously described anthropometric and PSG algorithm with the effective pressure determined using automatic titration. In addition, we found that leaks were common problems during CPAP titration and the pressure levels became signif-

icantly higher when the leak flow increased while performing automatic CPAP titration. Thus, the impact of leaks on the differences between PCPAPL and ACPAPL were also investigated.

METHODS

For this retrospective study, we enrolled 49 Taiwanese patients who were diagnosed with obstructive sleep apnea from March 2004 through August 2005. All of them had obstructive sleep apnea, defined by an AHI of > 5 ⁽¹⁸⁾ and confirmed using the initial diagnostic PSG. This was performed using a computerized system (N7000 Embula, somnologica, Iceland) including monitoring of the electroencephalogram (EEG), submental and anterior tibial electromyograms (EMG), oxygen saturation, electrocardiography (ECG), inductance plethysmography of chest wall and abdomen, nasal pressure sensor, and oronasal thermister. We scored the respiratory events as the report of sleep medicine task force and EEG using Rechtschaffen and Kales.⁽¹⁸⁾

A second CPAP titration study was performed to determine the optimal CPAP level using the AutoSet (ResMed, Sydney, Australia). The AutoSet system is a computer-based CPAP device that performs an automatic pressure titration. It automatically increases or decreases mask pressure in response to snoring, inspiration airflow contour morphology, or the presence of apneas or hyponpneas, thus acting to completely restore airway patency. Preparation of the patients was accomplished by a technician who supervised the study, and corrected the mask position and fitting initially. The lowest CPAP pressure (4 cm H₂O) applied to patients initially and automatic titration started when patients went to sleep. The summary report displays changes throughout the night CPAP pressure, mask leaks, and AHI index. The optimal CPAP pressure titrated automatically was determined using 95th percentiles pressure according to previous reports.^(7,8) The 95th percentiles pressure means the pressure level covers 95% of the study period and whose value is provided by the automated CPAP device.⁽⁸⁾ Intervals with excessive leaks (0.4 L/sec) were excluded from the analysis. We also recorded age, height, weight, and NC. The PCPAPL was calculated using anthropometric and polysomnographic formulas that were previously published (Predicting optimal CPAP = $0.52 + 0.174 \times \text{BMI} + 0.042 \times \text{AHI}$).

This formula was obtained from a Taiwanese population and was more accurate in predicting optimal CPAP pressure among our population.⁽¹⁵⁾ The leak flows were measured at liter per second (L/sec). The maximum leak (the biggest flow), median leak (middle value of leak during the study), and 95th percentile leak values (leak flow amount covering 95% of the study period) were used in our study.

Statistical evaluations were performed using computer analysis with SPSS Software (SPSS Inc., Chicago, Ill). Data were represented as mean ± standard deviation (SD). Comparison between PCPAPL and ACPAPL was done using the paired t-test. We used Spearman's correlation analysis to evaluate the relationship of ACPAP with mean leak, 95th percentiles leak, and maximum leak, BMI, NC, and AHI. A *p* value < 0.05 was considered statistically significant.

RESULTS

Comparison between PCPAPL and ACPAPL

A total of seven women and 42 men completed the diagnostic PSG study and automatic titration in our laboratory. Their anthropometry, AHI, CPAP level, and leak data are given in Table 1. Only four of them had mild obstructive sleep apnea and most of them had moderate to severe forms of diseases. The distribution of the differences between ACPAPL and

PCPAPL are shown in Fig. 1. The mean value of ACPAPL was significantly higher than the mean PCPAPL. The difference in the result was statistically significant (*p* < 0.001).

Correlation of PCPAP and ACPAP with leak value

We found that 98% of patients had air leaks during our study. The correlations of PCPAPL and ACPAPL and the differences among the three leak values were shown in Table 2. The PCPAPL had no correlation with any of the leak values but ACPAPL had good correlation with the maximum leak values (*p* = 0.002), median leak values (*p* = 0.001), and 95th percentile leak values (*p* = 0.034). The differences between the two CPAP values (ACPAPL - PCPAPL) also had significant correlation with the maximum leak (*p* = 0.036) and median leak values (*p* = 0.029), but there was only a weak correlation with 95th percentile leak value (*p* = 0.092). The results revealed both ACPAPL the and difference of the two CPAP values had positive correlation with leak values. That means the patients who had high leak values had higher ACPAPL and pressure differences between ACPAPL and PCPAPL.

Correlation of ACPAPL with anthropometry and AHI

We analyzed the correlation between ACPAPL with BMI, NC, and AHI. The correlation coefficients

Table 1. Anthropometric Characteristics, CPAP Pressure Level, and Leak Data

	Range	Mean ± SD
Age (yr)	24 - 74	53.2 ± 13
BMI (kg/m ²)	23 - 40.1	29.1 ± 4.1
NC (cm)	35.5 - 49	41.3 ± 3.4
AHI	9.4 - 101.6	53.2 ± 26.1
PCPAPL(cmH ₂ O)	4.36 - 11.39	7.03 ± 1.64
ACPAPL(cmH ₂ O)	7.4 - 16	10.4 ± 1.78
ACPAPL - PCPAPL(cmH ₂ O)	-2.99 - 8.55	3.37 ± 2.14
Maximum leak(L/sec)	0 - 2.2	0.42 ± 0.42
Median leak(L/sec)	0 - 0.38	0.07 ± 0.07
95 th Percentile leak(L/sec)	0 - 0.8	0.22 ± 0.15

Abbreviations: BMI: body mass index; NC: neck circumference; AHI: apnea/hypopnea index; ACPAPL: automatic continuous positive airway pressure titrating pressure level; PCPAPL: Predicting continuous positive airway pressure level; SD: standard deviation.

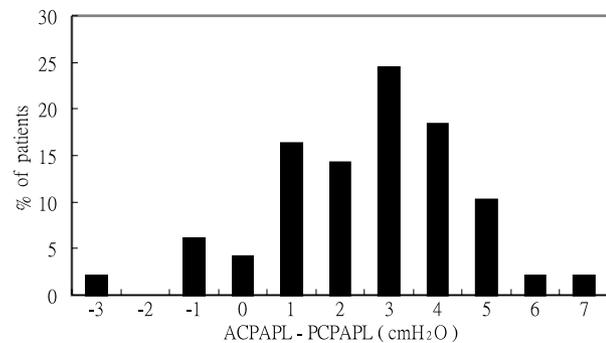


Fig. 1 Histogram of the difference between ACPAPL and PCPAPL. The ACPAPL were significantly higher than PCPAPL (95% CI 0.01 to 0.53). The ACPAPL equals the PCPAPL in around 4%, less in 8%, and greater in 88%. PCPAPL: Predicting continuous positive airway pressure level; ACPAPL: automatic continuous positive airway pressure titrating pressure level.

Table 2. Correlation of CPAP Pressure and Leak Values

Variable		Maximum leak	Median leak	95 th Percentile leak
PCPAPL	<i>p</i> Value	0.514	0.213	0.813
	Correlation coefficient	0.095	0.181	0.035
	95% CI	-0.191 to 0.366	-0.106 to 0.440	-0.249 to 0.313
ACPAPL	<i>p</i> Value	0.002	0.001	0.034
	Correlation coefficient	0.438*	0.458*	0.303*
	95% CI	0.179 to 0.640	0.203 to 0.655	0.024 to 0.538
ACPAPL - PCPAPL				
	<i>p</i> Value	0.036	0.029	0.092
Correlation coefficient	0.301*	0.312*	0.244	
	95% CI	0.022 to 0.537	0.034 to 0.545	-0.040 to 0.491

Abbreviation: PCPAPL: Predicting continuous positive airway pressure level; ACPAPL: automatic continuous positive airway pressure titrating pressure level.

* Correlation is significant at the 0.05 level (2-tailed).

are revealed in Table 3. The ACPAPL did not show a correlation with BMI ($p = 0.716$), NC ($p = 0.209$), or AHI ($p = 0.114$).

DISCUSSION

In our study, ACPAPL were significant higher than PCPAPL. The range of pressure difference between ACPAPL and PCPAPL were wide. A total of 98% of patients had air leaks during automatic CPAP titration. The ACPAPL had good correlation with leak values but did not have correlation with BMI, NC, or AHI.

Manual titration is still the gold standard to determine optimal CPAP pressure in current practice.^(5,7,19) Manual titration in the laboratory was used to monitor patient's status, select individualized fitting mask, and detect problems during CPAP titration. It was also used to resolve the discomfort in real time and gave patients much more education about CPAP therapy.⁽²⁰⁾ However, increased demands of manual CPAP titration have created long waiting lists and high cost.⁽⁷⁾ Several alternative methods

have been developed to determine optimal pressure. The two common alternative methods are automated CPAP titration and predictive method.^(7,15,20)

Automated CPAP titration is divided into home titration and attended titration in the laboratory. The main benefit of attended automatic titration is the reduction in technician work load which allows them to attend titration of more patients. The technicians are also able to intervene in real time problems and educate patients. On the other hand, home automated CPAP titration reduced the waiting list and is relatively low in cost, but it did not monitor patients or resolve the discomfort in real time.⁽²⁰⁾ The prediction of CPAP pressure using a formula that includes the AHI and anthropometric parameters has been proposed.⁽¹⁵⁾ The data were easily available and this could be used to simplify CPAP titration, but it did not monitor patients or resolve the discomfort in real time.

Some studies proved that manually titrating CPAP pressures were similar to those of attended automatic titration.^(8,9) To estimate CPAP pressure, PCPAPL equals the manually titrating pressure

Table 3. Correlation of Automatic Titrating CPAP Pressure with Apnea/Hypopnea Index and Anthropometry

Variable		AHI	BMI	NC
ACPAPL	<i>p</i> Value	0.114	0.716	0.209
	Correlation coefficient	0.228	-0.183	
	95% CI	-0.057 to 0.479	-0.232 to 0.329	-0.441 to 0.104

Abbreviations: ACPAPL: automatic continuous positive airway pressure titrating pressure level; AHI: apnea/hypopnea index; BMI: body mass index; NC: neck circumference.

* Correlation is significant at the 0.05 level (2-tailed).

around the same in 30%, less in 40% and greater in 30%.⁽²¹⁾ Theoretically, the PCPAPL and ACPAPL should have the same distribution with PCPAPL and manually titrating pressure. However, the ACPAPL were mostly higher than PCPAPL and the ACPAPL had good correlation with leak values as shown in our study. The ACPAPL did not correlate well with BMI, NC, or AHI. Therefore, we assume that the leakage is one of the important factors caused ACPAPL to be higher than PCPAPL.

The most of patients had air leaks in our study. The air leaks are commonly from mask leaks and mouth breathing. The air leaks from the mask could be corrected by selection of better fitting mask or adjusting the head straps. Mouth breathing during sleep prevents patient's adherence to CPAP therapy.^(22,23) The ACPAPL had positive correlation with leak values and selection of good fitting masks and check mask leaks were routine procedures when attended automatic CPAP titration was performed in our study. Therefore, we assume mouth leaks may be the reason for the correlation between ACPAPL and leak values, but further study is needed to confirm it.

In conclusion, ACPAPL were higher than PCPAPL. The range between ACPAPL and PCPAPL varied. Leakage was a common phenomenon during automatic CPAP titration. The most important factors effecting ACPAPL were leak values.

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自動壓力滴定與預估之陽壓呼吸器壓力值的比較

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背景：對於阻塞性睡眠呼吸中止症的病患正確的陽壓呼吸器壓力值更能有效改善白天嗜睡的症狀以及病患的健康狀況，目前並沒有文獻去比較自動型陽壓呼吸器壓力滴定法和預估壓力值的差異，因此本實驗的目的是比較自動型陽壓呼吸器壓力滴定法和預估陽壓呼吸器壓力值的差異，並進一步分析影響差異的因素。

方法：本回顧性研究對象是 49 位被診斷為阻塞性睡眠呼吸中止症的病患，並經醫師診治需要陽壓呼吸器治療，本研究使用百分之 95 的時間壓力值 (95th percentiles pressure) 做為自動滴定法的適合壓力值，另外利用身體質量指數 (body mass index)、頸圍 (neck circumference)、以及呼吸中止和低呼吸指數 (apnea/ hypopnea index) 的公式求出預估的壓力值，我們利用 t 測試 (paired t test) 去比較自動滴定法和預估壓力值是否有所不同，之外我們分析自動滴定法的壓力值是否與最大漏氣值 (maximum leak)、中位數漏氣值 (median leak values)、百分之 95 漏氣值 (95th percentile leak value)、身體質量指數、頸圍、呼吸中止和低呼吸指數相關。

結果：自動滴定法的平均壓力值 (10.4 ± 1.8 cmH₂O) 比預估的平均壓力值 (7.82 ± 1.51 cmH₂O) 在統計上有明顯偏高的情形 ($p < 0.001$)，百分之 98 的病患接受自動滴定法時會有漏氣的情形，自動滴定法的壓力值和最大漏氣值 ($r = 0.44$, 95% CI 0.18 to 0.64)、中位數漏氣值 ($r = 0.46$, 95% CI 0.20 to 0.66)、百分之 95 漏氣值 ($r = 0.30$, 95% CI 0.02 to 0.54) 有正相關性，而和身體質量指數 ($r = 0.05$, 95% CI -0.23 to 0.33)、頸圍 ($r = -0.18$, 95% CI -0.44 to 0.10)、呼吸中止和低呼吸指數 ($r = 0.23$, 95% CI -0.06 to 0.48) 並無相關性。

結論：自動型陽壓呼吸器壓力滴定法比預估的壓力值較高，並且兩種方法的壓力差異值變異性很大，漏氣在自動滴定法是很常見的，並且漏氣是影響自動滴定法壓力值的重要因素之一。

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關鍵詞：陽壓呼吸器，阻塞性睡眠呼吸中止症，自動型陽壓呼吸器，預估陽壓呼吸器壓力值，壓力測試，漏氣。