Correlates of a Prescription for Bilevel Positive Airway Pressure for Treatment of Obstructive Sleep Apnea among Veterans

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Introduction: The acceptance of portable home-based polysomnography together with auto-titrating CPAP has bypassed the need for a laboratory polysomnography. Since bilevel airway pressure (BPAP) is titrated in the sleep lab, patients diagnosed using portable home-based polysomnography may not have the opportunity to receive BPAP. It is unknown whether the patients who would have ordinarily received a BPAP would benefit from it. We determine correlates of receiving BPAP and of being switched from BPAP to CPAP. We examine whether patients with these correlates have better adherence to BPAP versus CPAP.

Methods: Retrospective Cohort Study (Correlates at baseline) of 2,513 VA patients with a sleep study between January 2003 and October 2006 and receiving continuous or bilevel positive airway pressure (CPAP [N = 2,251]) or BPAP (N = 262) by the end of 2007. PAP adherence up to 30 months was assessed.

Results: Significant correlates of BPAP were older age ($p < 0.001$), higher BMI and CHF ($p < 0.01$), COPD ($p < 0.001$),

higher blood CO₂ ($p < 0.05$), higher AHI and OSA severity ($p < 0.001$), lower nadir SpO₂ ($p < 0.001$), and greater sleepiness (ESS) ($p < 0.01$). Patients on BPAP were more adherent to PAP therapy ($p < 0.01$), but the association largely disappeared following adjustment for BPAP correlates. There was preliminary evidence that these correlates predict long-term adherence to PAP therapy regardless of mode.

Conclusions: We identified baseline factors that can help clinicians decide whether to prescribe an auto-BPAP as first-line therapy and that predict good long-term PAP adherence.

Keywords: Bilevel positive airway pressure, CPAP adherence, epidemiology, general, obstructive sleep apnea, veterans

Commentary: A commentary on this article appears in this issue on page 337.

Citation: Schwartz SW; Rosas J; Iannacone MR; Foulis PR; Anderson WM. Correlates of a prescription for bilevel positive airway pressure for treatment of obstructive sleep apnea among veterans. *J Clin Sleep Med* 2013;9(4):327-335.

Obstructive sleep apnea (OSA) afflicts 1 in 5 adults in the US.^{1,2} Continuous positive airway pressure (CPAP) is a highly effective treatment for OSA, eliminating almost all apneas, improving quality of life,³ and reducing accident rates⁴⁻⁶ and coronary events, including mortality.⁷⁻⁹ However, adherence to CPAP may be as low as 50%,^{10,11} thus limiting benefit. A probable reason for CPAP discontinuance is pressure intolerance^{12,13}; Lojander reported that 29% of his study patients had difficulty expiring against pressure.¹²

A remedy for pressure intolerance is bilevel continuous airway pressure (BPAP).^{14,15} BPAP is more expensive than CPAP¹⁶ but allows for a difference between inspiratory and expiratory pressures, resulting in more normal breathing for some patients.¹⁵ While two randomized clinical trials showed no difference in compliance (at 1 and 3 months, respectively) between BPAP and CPAP in small groups of OSA patients,¹⁶⁻¹⁸ patients non-adherent on CPAP often became adherent when switched to BPAP.^{19,20} BPAP is helpful to patients with hypoventilation^{15,21,22}; one study showed excellent compliance with BPAP in patients with alveolar hypoventilation, resulting in marked reduction of hypercapnia.¹⁵

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Sleep laboratories generally have a CPAP titration protocol that includes provisions for recommending BPAP, but many OSA patients are now diagnosed at home using portable equipment. Knowledge of patient factors that correlate strongly with BPAP preference would allow clinicians to priority-triage patients for in-laboratory full CPAP titration protocol or to prescribe auto-titrating BPAP.

Study Impact: Our data indicate that, when laboratory titration is not available, correlates of a BPAP prescription, including severity of OSA and concomitant COPD, among others, may be strong and robust enough to be useful in the decision to use a BPAP as first line therapy. We suggest that evidenced-based recommendations could be developed just based on specific comorbidities for first-line prescription of CPAP alternatives including but not limited to BPAP.

to the expense and limited availability of the sleep laboratory, however, many OSA patients are instead diagnosed at home using portable equipment, then prescribed auto-titrating CPAP if there is a positive OSA finding. In the James A. Haley Veterans hospital (JAHVA), one of the largest VA hospitals in the United States, 44% of patients prescribed CPAP are diagnosed outside the sleep lab.²⁶ The opportunity for such patients to initially receive a BPAP is thus severely curtailed. Because long-term

adherence to CPAP is highly associated with initial comfort,²⁷ it is possible that inability to prescribe BPAP may be a factor in long-term non-adherence: many patients may simply stop using CPAP rather than request an alternative. Knowledge of patient factors that correlate strongly with BPAP preference would allow clinicians to prioritize-triage patients for in-laboratory full CPAP titration protocol or to prescribe auto-titrating BPAP.

We are aware of only one small study of correlates of a BPAP prescription.¹³ It found that patients who required BPAP were more obese, had higher apnea-hypopnea index (AHI), lower mean SpO₂, lower FEV1 and FVC, and were more likely to have COPD and hypercapnia. More information is needed to guide clinical decisions. Our objectives were to (1) determine correlates of an initial BPAP prescription; (2) determine correlates of later being switched from CPAP to BPAP; and (3) examine whether adherence differs depending on PAP mode and whether these correlates predict better adherence to BPAP versus CPAP.

METHODS

The data come from a retrospective chart review of JAHVA patients to investigate the consequences of a procedural change from laboratory to home-based diagnosis and treatment of OSA. In mid-2006, 3,415 unique patients were identified from among 4 databases: (1) JAHVA Vista with a CPT code indicating a full lab polysomnogram; (2) pulmonary office prior-appointment schedule for the sleep lab; (3) pulmonary staff's log-out list for portable sleep diagnostic equipment; and (4) pulmonary quality control (QC) PAP adherence database.

Patients who never received a PAP (N = 304), had no PAP adherence data (N = 313), received a sleep study at JAHVA but received therapy and follow-up elsewhere (N = 198), whose PAP records started before January 1, 2002, or after December 31, 2007, or with no visit records in the year prior to their PAP (N = 87) were excluded. The latter exclusions ensured that all patients in the analysis would have a year of preexisting morbidity data and ≥ 3 years of PAP adherence data. Thus, our final dataset included 2,513 patients with sleep studies between January 2003 and October 2006 and who received CPAP or BPAP by December 2007.

The 2,513 patients included 1,220 patients with a sleep study in JAHVA lab, 870 patients with a sleep study from an outside lab, and 423 patients diagnosed in their home with portable equipment.

JAHVA Procedures for BPAP Receipt

Although data were obtained retrospectively, an understanding of how a patient receives BPAP is necessary for context. To date, patients at JAHVA do not receive a BPAP without a sleep laboratory titration, occurring either inside or outside the VA. *For initial BPAP prescription*, JAHVA Sleep laboratory technicians follow a PAP titration protocol that includes specific provisions for recommending BPAP rather than CPAP—for example, when CPAP exceeds 15 cm water and/or the patient begins to complain about exhaling against the pressure. A patient initially receiving a CPAP may be *switched from CPAP to BPAP as follows*: PAP compliance data is downloaded, and patients with problems (non-compliance or unresolved apnea)

are sent a form letter requesting they make an appointment at the respiratory PAP clinic. The PAP technician then refers the patient to the sleep laboratory for a titration study if: (1) the patient stills feels sleepy; (2) download data show uncorrected apnea although the patient is using the PAP, and/or (3) the PAP is set on maximum pressure (> 15 cm) with unresolved apnea.

PAP Adherence Measures

PAP adherence data from April 1, 2003, through October 2011 were obtained. Patients were asked to return their PAP card for download at 1 month, 1 year, and annually thereafter. PAP adherence data included therapy (BPAP or CPAP) and daily adherence records from the first date PAP was turned on. We defined 4 intervals: 2 weeks (days 1-21), 6 months (days 169-198), 18 months (days 534-563), and 30 months (days 899-928). We calculated average daily usage by taking the total number of hours used divided by the number of days in the interval and defined good adherence as average use ≥ 4 h per day. For patients who switched from CPAP to BPAP, adherence was measured separately for time on the respective therapy modes. Four patients who switched to BPAP within the first 30 days of PAP use did not contribute to CPAP adherence data.

Covariates

Measures from sleep studies (apnea-hypopnea index [AHI], nadir oxygen saturation [SpO₂], and total score on the Epworth Sleepiness Scale [ESS]) were obtained from the last baseline lab study if the patient had one; from the last laboratory pre-titration period from the split study if the patient only had a split study; and from the last portable sleep study if no lab sleep study was available. For some patients, particularly those with sleep studies outside the JAHVA, a diagnosis including severity of apnea was available, but not actual AHI. When AHI was available, we used it to define OSA severity as none/mild (0-14.9), moderate (15-29.9), and severe (≥ 30). There was a difference in completeness of sleep data available to us for in-house versus external lab polysomnography and for portable diagnosis. For patients bringing in their sleep study results from outside, a severity of apnea measure was available, but an explicit AHI or nadir SpO₂ was somewhat less likely to be captured in the pulmonary database. ESS was only rarely captured from outside lab studies. Patients diagnosed using a portable system often did not have an ESS.

The index date for evaluating comorbidities is the date the patient first received a PAP prescription. Demographics, laboratory, vital signs, pharmacy, outpatient and inpatient records from 2002 through March 2010 were reviewed. We determined comorbidities, using ICD-9 codes for any outpatient or inpatient visit from 1 year prior to PAP start through 6 months after PAP start. We also summarized data for hypertension (ICD 401-405), diabetes mellitus (ICD 6), heart failure (ICD 402, 425, 428), COPD (ICD 491-494, 496, 415.0, 416.8, 416.9), thyroid disorders (ICD 242-244), depression (ICD 311), traumatic stress disorder (ICD 309.81), and combined physical neurologic disorders (ICDs 323, 331-337, 340-342, 344, 358). The Charlson Morbidity Index was calculated using the method of Deyo.²⁸ Tobacco abuse was evaluated across all available records pre or post PAP start. BMI was taken as the mean of the value closest to the index date within one year before PAP start

Table 1—Number of patients with non-missing values for each covariate or outcome

Characteristic	Objective 1: Patients Diagnosed in Sleep-Lab [†]				Objective 2: All Patients Except Those Initially Prescribed BPAP, Includes Portable	
	JAHVA Lab Only		All in-Lab Patients		Switched to BPAP	Remained on CPAP
	Titrated BPAP	Titrated CPAP	Titrated BPAP	Titrated CPAP		
Included Patients	170	1,050	259	1,831	110	2,140
Age/Gender	170	1,050	259	1,831	110	2,140
BMI, kg/m ²	152	997	228	1,731	105	2,017
Race	148	931	231	1,648	93	1,920
Hispanic	158	962	242	1,689	94	1,988
Marital Status	170	1,048	259	1,828	110	2,135
Comorbidities	170	1,050	259	1,831	110	2,140
Lab: Blood CO ₂	161	994	249	1,726	105	2,020
AHI [‡]	151	937	184	1,348	82	1,683
OSA severity	157	948	194	1,396	89	1,725
Nadir SpO ₂	149	920	183	1,320	78	1,643
Epworth Sleepiness Scale [*]	140	814	149	849	57	814
PAP Adherence						
2 weeks	170	1,048	259	1,828	110	2,140
6 months	124	679	191	1,249	85	1,449
18 months	97	507	153	972	59	1,128
30 months	70	404	112	786	38	918

[†]Objective 1 is to determine correlates of an initial BPAP prescription. Two sets of analyses are done: (1) Restricted to patients diagnosed in the JAHVA Lab and (2) Including all in-Lab patients. Objective 2 is to determine correlates of later being switched from CPAP to BPAP. [‡]For some patients, particularly those diagnosed outside the VA, the severity of apnea was recorded, but the AHI was unavailable. However, if the patient had an AHI, we based apnea severity on the AHI. ^{*}The Epworth Sleepiness Scale was usually available only for patients diagnosed in the JAHVA sleep lab.

and the value closest to the index date within one year after PAP start, if both were available; otherwise, only one measure was used. The closest venous sample CO₂ taken within one year prior to PAP initiation was used. Most were plasma samples, but for 30 patients without CO₂ measures, we used arterial bicarbonate measure (Table 1).

Population Subsamples and Analysis Methods

Objective 1. Determine correlates of an initial BPAP receipt among patients diagnosed in a sleep lab

We did two complete sets of analyses using patients with full laboratory polysomnography to meet this objective: (1) an analysis restricted to patients with a study conducted at JAHVA sleep lab; (2) an analysis that included all patients diagnosed in a sleep lab, whether at JAHVA or from outside. The most obvious difference between JAHVA and outside lab patients was the presence of an ESS measure, but there might also be patient differences between groups; during some of the baseline years, there was a 2-year wait for the JAHVA sleep lab, so patients going outside might have had alternate insurance or be more concerned about their health.

The Wilcoxon rank-sum test (continuous variables) or χ^2 test (categorical variables) were used to screen correlates. Associations are presented as odds ratios (BPAP vs CPAP), given levels of categorical variables (or categorized continuous variables) from logistic regression. To find the best predictive models, covariates in Table 2 were entered into stepwise logistic regres-

sion procedure, with selection probabilities to 0.2 to enter and 0.1 to stay in the model. For continuous variables, we examined both the raw variable and categorized variable for better fit. Lastly, we re-ran the final stepwise model on the full dataset to minimize loss of observations due to missing values. Because ESS was usually available only for patients diagnosed in the JAHVA lab, it was included in stepwise analyses only when the analysis was restricted to JAHVA lab patients.

Objective 2. Determine correlates of being switched from CPAP to BPAP

This analysis included all patients in our dataset except those initially prescribed BPAP. Patients who were originally diagnosed using portable equipment were included along with lab-diagnosed patients, as they provide more cases of patients initially prescribed CPAP who were switched later to BPAP. This objective is evaluated by comparing CPAP patients switched to BPAP vs. those remaining on CPAP using the same analysis methods and strategy described for objective 1.

Objective 3a. Determine whether adherence was better with BPAP than CPAP, controlling for patient differences

Adherence was compared between CPAP and BPAP recipients within the entire cohort (N = 2,513), separately by time period, using univariate logistic regression. To determine if differences in adherence were due to differences in patient characteristics (e.g., comorbidities) or qualities of BPAP itself, we conducted the comparison controlling for patient differences as

Table 2—Objective 1: Summary* of potential correlates of an initial BPAP vs CPAP prescription

	JAHVA Lab Only			All In-Lab Patients		
	Titrated BPAP	Titrated CPAP		Titrated BPAP	Titrated CPAP	
Age	62.18 ± 9.9	59.16 ± 11.1	^c	61.53 ± 10.4	59.26 ± 11.1	^b
Female	6 (3.5)	60 (5.7)		7 (2.7)	93 (5.1)	^d
BMI, kg/m ²	37.15 ± 7.9	33.99 ± 6.9	^c	37.70 ± 8.2	34.35 ± 6.9	^c
Race						
White	131 (88.5)	783 (84.1)		205 (88.7)	1,397 (84.8)	
Black	13 (8.8)	113 (12.1)		22 (9.5)	189 (11.5)	
Other	4 (2.7)	35 (3.8)		4 (1.7)	62 (3.8)	
Hispanic	7 (4.4)	74 (7.7)		16 (6.6)	123 (7.3)	
Marital Status						
Married	116 (68.2)	727 (69.4)		174 (67.2)	1,276 (69.8)	
Widowed	12 (7.1)	58 (5.5)		18 (6.9)	94 (5.1)	
Single/Divorced	42 (24.7)	263 (25.1)		67 (25.9)	458 (25.1)	
Charlson Index	2.25 ± 2.2	1.75 ± 1.8	^b	2.27 ± 2.1	1.70 ± 1.8	^c
CHF	39 (22.9)	149 (14.2)	^b	57 (22.0)	246 (13.4)	^c
COPD	77 (45.3)	317 (30.2)	^c	123 (47.5)	505 (27.6)	^c
Diabetes Mellitus	70 (41.2)	407 (38.8)		116 (44.8)	738 (40.3)	
Hypertension	130 (76.5)	777 (74.0)		202 (78.0)	1,387 (75.8)	
Record of Tobacco Abuse	34 (20.0)	203 (19.3)		57 (22.0)	320 (17.5)	^d
Posttraumatic Stress	24 (14.1)	185 (17.6)		30 (11.6)	293 (16.0)	^d
Depressive Disorder	30 (17.6)	234 (22.3)		45 (17.4)	406 (22.2)	^d
Neurologic diagnosis	31 (18.2)	160 (15.2)		40 (15.4)	231 (12.6)	
Thyroid diagnosis	15 (8.8)	91 (8.7)		25 (9.7)	149 (8.1)	
Lab: Blood CO ₂	28.22 ± 4.2	27.52 ± 3.3	^a	28.70 ± 4.5	27.57 ± 3.2	^c
AHI	60.38 ± 32.2	38.73 ± 30.1	^c	59.39 ± 32.7	38.86 ± 29.3	^c
Nadir SpO ₂	77.57 ± 9.6	81.05 ± 8.4	^c	76.71 ± 10.3	80.44 ± 9.0	^c
Epworth Sleepiness Scale†	14.31 ± 5.4	12.55 ± 6.0	^b	14.23 ± 5.5	12.57 ± 6.0	^b

*n (%) or mean ± SD. ^ap < 0.05, ^bp < 0.01, ^cp < 0.001 for difference between groups. Univariate analysis using Wilcoxon rank-sum (continuous variables) or χ^2 test (categorical variables). ^dDifference between groups is borderline significant, 0.05 < p < 0.1. †Epworth Sleepiness Scale was usually available only for patients diagnosed in the JAHVA sleep lab.

described below. These analyses used the 1,765 (of 2,513) with non-missing covariate data (**Table 1**).

Simultaneous control of all covariates was accomplished using propensity scores (PS).²⁹ The PS is an individual's probability of BPAP receipt based on his/her covariates, as calculated from logistic regression. The PS can be considered a summary of that person's covariates, where high PS reflects a patient whose covariates are associated with receiving BPAP and low PS a patient whose covariates are associated with receiving CPAP, irrespective of actual mode received. Propensity scores for patients diagnosed with portable equipment were calculated using coefficients from the model developed from sleep lab patients, as $\exp(\alpha + \beta X) / [1 + \exp(\alpha + \beta X)]$ where βX denotes the sum of age, BMI, COPD, any neurology diagnosis, AHI, and SpO₂, each multiplied by its respective logistic coefficient.

We divided patients into two groups: those with covariates likely to lead to BPAP prescription (PS in top 25%) vs. those less likely (PS in bottom 75%), irrespective of mode prescribed. Then within each of these PS strata, we evaluated the difference in adherence for BPAP recipients vs. CPAP recipients separately by time point. Secondly, we ran bivariate models comparing

therapy mode (BPAP versus CPAP), controlling for PS stratum (top quartile vs. lower three).

Objective 3b. To examine whether correlates of a BPAP prescription predict better adherence to BPAP vs. CPAP

If the “right” patients are receiving BPAP then we expect superior adherence with BPAP (vs. CPAP) would be greater among patients with a higher propensity score for receiving BPAP. We addressed this by adding a therapy-by-PS-stratum interaction term to the models for this objective.

RESULTS

Patients ranged in age from 21 to 90 years (mean 59.7 ± 11.1). The sample was 95% male and 86% white, and BMI ranged from 15 to 69 (mean 34.6 ± 7.1; data not shown).

Unadjusted results (means or percentages) for Objectives 1 and 2 are given in **Tables 2** and **3**, respectively. Unadjusted odds ratios are given for important covariates (both objectives) in **Table 4**. For Objective 1, results for JAHVA-lab and any-lab diagnosed patients diagnosed were very similar (**Table 2**), so we refer here only to the latter. Baseline factors that dif-

ferred significantly between groups, predicting both the initial BPAP prescription (Tables 2, 4) and a later change to BPAP (Tables 3, 4) were higher BMI (OR 2.69 and 1.67, respectively), heart failure (OR 1.82 and 1.91, respectively), higher blood CO₂ (OR 1.74 and 2.11, respectively), severe OSA (OR 4.27 and 2.52, respectively), and a lower nadir SpO₂ (OR 2.97 and 1.88, respectively) (Tables 2-4). Additional factors associated with the initial BPAP prescription were COPD (OR 2.37), the overall morbidity index 2+ vs < 2 (OR 1.80, not shown); and ESS (OR 2.17 modeled only with patients with a JAHVA lab sleep study).

The final stepwise models showed BMI, COPD, and AHI as independent joint predictors of both an initial BPAP prescription and a later change from CPAP to BPAP. Additional predictors of an initial BPAP prescription were age and nadir SpO₂. Among the JAHVA-lab tested patients, ESS was selected by the stepwise procedure. In the final stepwise models, a neurologic disorder was also a predictor of receiving BPAP, and blood CO₂ emerged as a predictor of later change from CPAP to BPAP (Table 5), though this was due to the liberal modeling criteria: $p = 0.2$ and $p = 0.1$ for entry and staying, respectively.

Adherence

Patients prescribed BPAP appeared more compliant than those prescribed CPAP, both immediately and long-term (Table 6, Figure 1). Initial (2-week) adherence was 67% and 55% on BPAP and CPAP, respectively, and at 30 months 85% vs. 74%, respectively (OR 1.98, 95%CI 1.16-3.38). CPAP patients later switched to BPAP were initially much more compliant than those not switched (75% versus 54%), with a trend toward better adherence with BPAP persisting at later time points.

Adjusting for patient differences between BPAP and CPAP reduced the observed improved adherence with BPAP to non-significance for all time points except 2 weeks (Table 6). Associations were sometimes lower for each propensity group than overall, which indicates that patient correlates confound and are partially responsible for the association between BPAP and adherence.

Interestingly, propensity score stratum turned out to be a highly significant predictor of adherence for all time points after 2 weeks, even when controlling for therapy mode (Table 6). The interaction between therapy mode and PS was not significant ($p > 0.25$), nor was there evidence of interaction between propensity score and being switched to BPAP (data not shown).

DISCUSSION

We determined that independent correlates of a BPAP prescription include older age, higher BMI, COPD, elevated blood CO₂, severe OSA, low nadir SpO₂, and sleepiness. We found that these correlates tended to be robust. Further, we found that a summary measure of these indicators predicts long-term adherence to PAP therapy.

Some comorbidities such as CHF were—on their own—highly significant predictors of BPAP, but were not significant when controlling for other factors. This only means that they are redundant with other correlates. CHF may manifest in low nadir nocturnal oxygen and possibly higher AHI.

Table 3—Objective 2: Summary* of potential correlates of being switched from CPAP to BPAP vs remaining on CPAP

	Objective 2: All Patients Except Those Initially Prescribed BPAP, Includes Portable	
	Switched to BPAP	Remained on CPAP
Age	59.99 ± 9.9	59.46 ± 11.2
Female	4 (3.6)	103 (4.8)
BMI, kg/m ²	36.75 ± 7.9	34.13 ± 6.8 ^c
Race		
White	86 (92.5)	1,645 (85.7)
Black	5 (5.4)	205 (10.7)
Other	2 (2.2)	70 (3.6)
Hispanic	4 (4.3)	148 (7.4)
Marital Status		
Married	75 (68.2)	1,488 (69.7)
Widowed	5 (4.5)	109 (5.1)
Single/Divorced	30 (27.3)	538 (25.2)
Charlson Index	1.90 ± 1.8	1.70 ± 1.8
Congestive Heart Failure	25 (22.7)	286 (13.4) ^b
COPD	37 (33.6)	580 (27.1)
Diabetes Mellitus	52 (47.3)	845 (39.5)
Hypertension	90 (81.8)	1,609 (75.2)
Record of Tobacco Abuse	19 (17.3)	400 (18.7)
Posttraumatic Stress	20 (18.2)	334 (15.6)
Depressive Disorder	29 (26.4)	435 (20.3)
Neurologic Diagnosis	19 (17.3)	253 (11.8) ^d
Thyroid Diagnosis	11 (10.0)	164 (7.7)
Lab: Blood CO ₂	28.29 ± 3.2	27.60 ± 3.2 ^a
AHI	49.20 ± 30.2	37.04 ± 26.9 ^c
Nadir SpO ₂	76.53 ± 11.5	79.35 ± 9.7 ^a
Epworth Sleepiness Scale	14.81 ± 8.9	12.45 ± 5.9 ^b

*n (%) or mean ± SD. ^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$ for difference between groups. Univariate analysis using Wilcoxon rank-sum (continuous variables) or χ^2 test (categorical variables). ^dDifference between groups is borderline significant, $0.05 < p < 0.1$.

We did obtain some preliminary evidence of an association of a BPAP prescription with neurologic disorders, which included Parkinson disease, ALS, and MS, after adjustment for other factors. Such patients may not have adequate muscle tone to exhale against higher pressures. There are several reports of the helpfulness of BPAP in patients with ALS and neuromuscular disorders.^{33,34} We did not find an association with diabetes, hypertension, thyroid disorders, depression, traumatic stress disorder, race, Hispanic origin, or marital status.

At JAHVA, BPAP is recommended during laboratory titration by the attending technician according to protocol. Given the VA laboratory protocol, it is highly likely that the correlates we identified are all associated with either difficult-to-treat apneas or patient difficulty expiring at higher pressure. Our findings emphasize that patients identified by this protocol tend to have specific comorbidities that are prominent indications for BPAP in the literature. For example, a recent clinical trial from Russia on COPD patients indicated that BPAP was much more

Table 4—Odds ratios for BPAP receipt for categories of selected characteristics

	Objective 1: Patients Titrated in the Sleep Laboratory						Objective 2: All Patients Except Those Initially Prescribed BPAP, Includes Portable		
	JAHVA Lab Only			All In-Lab			Switched to BPAP vs Remained on CPAP		
	Counts BPAP CPAP	BPAP vs CPAP OR (95% CI)*		Counts BPAP CPAP	BPAP vs CPAP OR (95% CI)		Counts BPAP CPAP	Switched to BPAP vs Remained on CPAP OR (95% CI)	
Age									
21-49	19 180	REF		33 326	REF		12 377	REF	
50-69	113 681	1.57 (0.94, 2.63)		167 1,167	1.41 (0.95, 2.09)		82 1,356	1.90 (1.03, 3.52)	
70+	38 189	1.90 (1.06, 3.43)		59 338	1.72 (1.10, 2.71)		16 407	1.24 (0.58, 2.64)	
BMI									
< 31	29 354	REF		39 581	REF		30 680	REF	
31-34	33 199	2.02 (1.19, 3.43)		44 348	1.88 (1.20, 2.96)		9 442	0.46 (0.22, 0.98)	
> 34	90 444	2.47 (1.59, 3.85)		145 802	2.69 (1.86, 3.90)		66 895	1.67 (1.07, 2.60)	
CHF									
Yes/No	39 149	1.80 (1.21, 2.68)		57 246	1.82 (1.32, 2.51)		25 286	1.91 (1.20, 3.03)	
COPD									
Yes/No	77 317	1.91 (1.38, 2.66)		123 505	2.37 (1.82, 3.09)		37 580	1.36 (0.91, 2.05)	
Blood CO₂									
< 26	40 273	REF		53 443	REF		17 505	REF	
26-29	66 471	0.96 (0.63, 1.46)		107 855	1.05 (0.74, 1.48)		52 1,008	1.53 (0.88, 2.68)	
> 29	55 250	1.50 (0.97, 2.34)		89 428	1.74 (1.21, 2.50)		36 507	2.11 (1.17, 3.80)	
OSA sev									
Mild/None	12 229	REF		15 302	REF		11 356	REF	
Moderate	19 247	1.47 (0.70, 3.09)		26 373	1.40 (0.73, 2.70)		10 496	0.65 (0.27, 1.55)	
Severe	126 472	5.09 (2.76, 9.40)		153 721	4.27 (2.47, 7.38)		68 873	2.52 (1.32, 4.82)	
Nadir SpO₂									
> 85%	24 319	REF		30 447	REF		17 498	REF	
77-85%	75 393	2.54 (1.57, 4.11)		86 537	2.39 (1.55, 3.68)		29 646	1.32 (0.71, 2.42)	
< 77%	50 208	3.19 (1.90, 5.36)		67 336	2.97 (1.89, 4.67)		32 499	1.88 (1.03, 3.43)	
ESS									
< 10	33 264	REF		36 275	REF		14 271	REF	
10-15	39 299	1.04 (0.64, 1.71)		42 309	1.04 (0.65, 1.67)		23 291	1.53 (0.77, 3.03)	
> 15	68 251	2.17 (1.38, 3.40)		71 265	2.05 (1.32, 3.16)		20 252	1.54 (0.76, 3.11)	

*Bold typeface for odds ratios indicates that odds ratio is significantly different from 1.000, $p < 0.05$.

Table 5—Final multivariate models: results of stepwise selection*

	Objective 1: Patients Titrated in the Sleep Laboratory		Objective 2: All Patients Except Those Initially Prescribed BPAP, Includes Portable
	JAHVA Lab Only BPAP vs CPAP	All In-Lab BPAP vs CPAP	Switched to BPAP vs Remained on CPAP
Age (per year)	1.038 (1.015, 1.060)	1.034 (1.016, 1.052)	
BMI (per kg/m ²)	1.039 (1.009, 1.071)	1.034 (1.009, 1.060)	1.041 (1.009, 1.074)
COPD	1.756 (1.140, 2.705)	2.175 (1.521, 3.110)	1.741 (1.061, 2.858)
Neurologic Diagnosis		1.449 (0.886, 2.371)	
Blood CO ₂ (per mmol/L)			1.056 (0.984, 1.132)
AHI (per event/h)	1.013 (1.007, 1.020)	1.017 (1.011, 1.022)	1.011 (1.003, 1.018)
Nadir SpO ₂ (per %)		0.977 (0.960, 0.994)	
Nadir SpO ₂ 77-85 vs > 85	2.008 (1.128, 3.574)		
Nadir SpO ₂ < 77 vs > 85	1.952 (1.037, 3.676)		
ESS (per scale unit)	1.059 (1.018, 1.101)	Not allowed†	Not allowed†

All values are OR (95% CI). Bold typeface for odds ratios indicates that odds ratio is significantly different from 1.000, $p < 0.05$. *From logistic regression model run on full data set using covariates selected from stepwise regression procedure. The model used $p = 0.2$ and $p = 0.1$ for entry and staying respectively, so not all variables are statistically significant at the 0.05 level. †ESS was not screened in final model because of too many missing values. Odds ratios for continuous variables are expressed as increase in odds per unit increase in the covariate (e.g., 1 year older age or 1 mmol/L CO₂). The OR of 1.035 per year of age corresponds to an OR of 1.41 for a 10-year difference ($OR_{10\text{Years}} = \exp(\ln(OR) \times 10)$).

Table 6—Comparisons between groups on PAP adherence, total unadjusted, stratified by propensity score, and adjusted for propensity score*

Comparison		OR (95% CI) [†]
Unadjusted For Propensity Score		
2 weeks	BPAP vs CPAP	1.697 (1.294, 2.224)
6 months	BPAP vs CPAP	1.549 (1.115, 2.153)
18 months	BPAP vs CPAP	1.618 (1.089, 2.404)
30 months	BPAP vs CPAP	1.976 (1.156, 3.378)
Stratified by Propensity Score		
Low Propensity		
2 weeks	BPAP vs CPAP	2.036 (1.249, 3.318)
6 months	BPAP vs CPAP	1.106 (0.640, 1.911)
18 months	BPAP vs CPAP	1.067 (0.581, 1.959)
30 months	BPAP vs CPAP	1.011 (0.489, 2.091)
High Propensity		
2 weeks	BPAP vs CPAP	1.118 (0.687, 1.819)
6 months	BPAP vs CPAP	1.068 (0.601, 1.910)
18 months	BPAP vs CPAP	1.097 (0.540, 2.227)
30 months	BPAP vs CPAP	2.841 (0.817, 9.878)
Model Including Treatment and Propensity Score		
2 weeks	High vs Low Propensity	1.212 (0.971, 1.514)
	BPAP vs CPAP	1.523 (1.081, 2.144)
6 months	High vs Low Propensity	1.425 (1.078, 1.882)
	BPAP vs CPAP	1.088 (0.732, 1.617)
18 months	High vs Low Propensity	1.510 (1.078, 2.115)
	BPAP vs CPAP	1.080 (0.681, 1.713)
30 months	High vs Low Propensity	1.784 (1.172, 2.716)
	BPAP vs CPAP	1.396 (0.753, 2.587)

*Unadjusted odds ratios are based on full cohort of 2,513 patients. Adjusted and stratified odds ratios are based on 1,765 patients with data for all of the following covariates that were used to calculate propensity score: Age, BMI, COPD, neurologic DX, AHI, and nadir SpO₂. [†]Bold typeface for odds ratios indicates that odds ratio is significantly different from 1.000, $p < 0.05$.

effective than CPAP in affecting the desaturation index.³⁰ It now appears that many clinicians are accepting BPAP as the standard of care in patients with hypercapnia and hypoventilation syndrome.^{31,32} Indeed, obesity-hypoventilation syndrome may explain the strength of the association we noted between high BMI and a BPAP prescription.

It has been stated that the benefits of BPAP and other advancements to CPAP remain unproven.³⁷ We saw overall improved adherence among BPAP versus CPAP patients, but the difference largely disappeared after controlling for patient characteristics. In our data, the improved adherence among BPAP recipients appears to be related to patient characteristics. While others have reported that severity of OSA and/or low nadir SpO₂ predict adherence,^{38,39} our propensity score—a summary measure of several patient characteristics—was a stronger predictor of long-term PAP adherence than BPAP itself. It appears that in finding correlates of BPAP prescription, we may have serendipitously created a method to predict long-term PAP adherence.

Previous clinical trials that found no benefit to BPAP¹⁶⁻¹⁸ may be misleading if interaction (persons with severe disease do better on BPAP but those with less severe do not) obscures

Figure 1

(A) Percentage of patients, initially prescribed BPAP versus CPAP, using PAP on average more than 4 h/day (based on entire cohort of 2,513 patients). (B) Percentage of patients switched to BPAP versus remaining on CPAP, using PAP on average more than 4 h/day.

an overall effect. We were unable to demonstrate a comparative benefit of BPAP versus CPAP among sicker patients. This may be due to relatively low statistical power to test interaction. This question should be studied further either by looking at interaction in a still larger study, or (if ethical) by a comparative

randomized clinical study restricted to patients with high propensity for receiving BPAP.

The baseline measures for nearly all patients in our study were collected before the Portable Monitoring Taskforce (PMT) published their clinical guidelines on which OCSST guidelines are based, in 2007.⁴⁰ Prior to the PMT publication and our own quality control studies, JAHVA patients were triaged to a portable or laboratory sleep study based on patient preference and/or the triage nurse's judgment as to whether the patient would successfully complete the unattended sleep study. Most of the correlates that we highlight—older age, COPD, CHF, and indirectly obesity hyperventilation syndrome (higher BMI and blood CO₂)—are listed in the PMT guidelines either as contraindications for portable monitoring or necessitating caution because patients with these conditions have not been adequately studied. Our study provides strong empirical support for following these guidelines: patients undergoing diagnosis with portable equipment simply do not have simultaneous access to a titration study necessary to dispense appropriate treatment to those who require devices beyond CPAP.

Our data indicate that, when laboratory titration is not available, correlates of a BPAP prescription may be strong and robust enough to be useful in the decision to use a BPAP as first line therapy. Given the high prevalence of OSA coupled with comorbidities, especially among Veterans, we pose the question of whether evidenced-based recommendations could be developed just based on specific comorbidities, for first-line prescription of CPAP alternatives including but not limited to BPAP.

Our data were retrospectively collected from patient electronic charts, and correlates, including blood CO₂, could have been assessed a full year before PAP was dispensed. Since data from BPAP and CPAP patients are handled the same way, misclassification (if it occurred) would be non-differential and make groups more similar rather than exaggerate associations.^{35,36}

Further limitations of this study include the fact that type of apneas (obstructive versus central) was not captured. Similarly, while the propensity score summarizes key comorbidities, it does not include comorbidities or other patient characteristics for which data were not available. There is a potential limitation in adherence data if the likelihood of patients returning adherence cards was related to adherence itself (i.e., poor adherers less likely to submit data). Unfortunately it is not possible to detect or correct for this analytically; however, it is unlikely that this behavior (if it occurred) would differ between BPAP and CPAP groups and therefore bias our results. There is also an additional bias at later time points created by patients being switched to BPAP. If a patient switches from CPAP to BPAP late in the study because of trouble with CPAP, he is excluded from the CPAP group at the time of the switch. The direction of the bias depends on whether these patients would have remained adherent to CPAP had they not been switched to BPAP. If not, then once again, our results are understated. We see no way to address this particular limitation analytically.

Strengths of the study include the large sample size and the consistency of overall results (e.g., all sleep lab patients with JAHVA sleep lab patients).

In summary, we determined that such morbidity indicators as older age, high BMI, COPD, blood CO₂, OSA severity, nadir

SpO₂, and sleepiness can perhaps be used to decide whether BPAP should be used as first-line therapy when PAP titration is not part of the diagnostic procedure. This would speed up time to appropriate treatment and make more efficient use of sleep labs. Further, we found that a summary measure of these indicators predicts long-term adherence to PAP therapy in general. We recommend future research to develop and confirm an algorithm that can be used to decide whether to prescribe an auto-BPAP and to predict long-term adherence. We also recommend that future research on the comparative efficacy and cost effectiveness of BPAP be restricted to patients who would normally be prescribed a BPAP. Lastly, our retrospective study had no opportunity to measure PAP-related quality of life. While our results highlight that sicker people are more adherent to PAP therapy, regardless of type, it may be that they are more comfortable and enjoy better quality of life using BPAP. More research is needed in this area as well.

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ACKNOWLEDGMENTS

The authors gratefully acknowledge JAHVH for its support of this research. The views expressed here do not necessarily reflect the views of the Veterans Administration. This material is the result of work supported with resources and the use of facilities at the James A. Haley Veterans Hospital, Tampa Florida, Office of Research and Development Health Services Research and Development Service, and Rehabilitation Research and Development. This study was approved by the Research and Development Committee, James A. Haley Veterans Hospital and Institutional Review Board, University of South Florida. There was no financial support and no author has a conflict of interest. The authors also gratefully acknowledge the editorial assistance provided by Debra Weiner.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication April, 2012

Submitted in final revised form August, 2012

Accepted for publication September, 2012

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DISCLOSURE STATEMENT

This was not an industry supported study. The authors have indicated no financial conflicts of interest.