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SCIENTIFIC INVESTIGATIONS

CPAP adherence is associated with reduced inpatient utilization among older adult Medicare beneficiaries with pre-existing cardiovascular disease

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Study Objectives: To examine the impact of adherence to continuous positive airway pressure (CPAP) therapy on health care utilization among a nationally representative and sample of older adults with multiple morbidities and pre-existing cardiovascular disease and subsequently diagnosed with obstructive sleep apnea in the United States.

Methods: Our data source was a random 5% sample of Medicare administrative claims data. All participants (n = 1,921) were of age ≥ 65 years, diagnosed with cardiovascular disease and obstructive sleep apnea, and subsequently began treatment with CPAP between 2009–2013. Based on the number of CPAP machine charges, individuals were categorized as low, partial, or high adherers (ie, < 4, 4–12, and > 12 CPAP charges, respectively). The impact of CPAP adherence status on health care utilization was assessed across multiple points of service, including outpatient encounters, inpatient stays, emergency department visits, and prescription fills over 24 months following CPAP initiation.

Results: Significant differences in demographic and comorbid disease characteristics were observed between low adherers (n = 377), partial adherers (n = 236), and high adherers (n = 1,308). After adjusting for covariates and relative to low adherers, high adherers demonstrated reduced inpatient visits (hazard ratio 0.75; 95% confidence interval 0.57, 0.97).

Conclusions: In this nationally representative sample of older Medicare beneficiaries with multiple morbidities and relative to low adherers, high adherers demonstrated reduced inpatient utilization.

Keywords: sleep, obstructive sleep apnea, cardiovascular, multimorbidity, treatment, positive airway pressure, CPAP, health care utilization, health economics, costs, Medicare, older adults

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Obstructive sleep apnea is associated with a well documented increased risk for cardiovascular disease (CVD). As well, both obstructive sleep apnea and cardiovascular disease are associated with increased health care utilization (HCU); indeed, cardiovascular disease is among the most expensive chronic diseases worldwide. Despite these associations, relatively less is known about the potential impact of obstructive sleep apnea treatment on HCU. Several studies suggest that treatment of obstructive sleep apnea reduces HCU, but most studies to date have been limited by small clinical samples and unknown generalizability. To advance understanding, the purpose of the present study was to evaluate the impact of continuous positive airway pressure (CPAP) adherence on HCU among a national sample of older adults with multiple morbidities and cardiovascular disease.

Study Impact: In this national analysis of older adult Medicare beneficiaries with multiple morbidities and CVD, significant demographic and disease comorbidity differences were observed between CPAP low adherers, partial adherers, and high adherers. In an adjusted logistic regression model, CPAP high adherers demonstrated reduced hospital HCU (inpatient stays). These results add an important population health perspective to the expanding literature demonstrating positive health economic benefit associated with CPAP adherence. Further, present results suggest achieving CPAP adherence as an important clinical and population health objective in this population.

INTRODUCTION

Multimorbidity is increasingly recognized as one of the most important health care challenges impacting older adults. In the United States nearly 70% of adults aged 65 and older experience at least 2 chronic conditions concurrently, creating challenges for disease management, worsening health outcomes, and increasing health care utilization.[1] Among comorbidities contributing to multimorbidity, obstructive sleep apnea (OSA) is a common and costly medical condition associated with worsened health-related, quality of life, and economic outcomes. OSA is associated with increased risk for cardiovascular disease (CVD),[2–4] stroke,[5,6] metabolic syndromes and type 2 diabetes,[7–9] depression,[10] reduced quality of life,[11] accidents and injuries,[12]

and premature death.[13,14] The prevalence of moderate to severe OSA is approximately 14% among men and 5% among women between the ages of 30 and 70 years.[15] The prevalence of OSA increases with age and is highest among older adults,[16] impacting up to 70% of elderly nursing home residents, who are, in turn, at increased risk for mortality and dying during sleep.[17]

Beyond these well-documented clinical consequences, among older adults OSA is associated with adverse economic outcomes, including increased health care utilization (HCU)[18] and costs.[19,20] For example, Wickwire and colleagues[21] recently found that relative to matched nonsleep disordered controls (n = 333,039), Medicare beneficiaries with OSA (n = 14,963) demonstrated greater HCU and costs across all points of service assessed, including outpatient encounters, emergency department visits, inpatient stays, and prescription HCU and costs.

Given the substantial economic burden associated with untreated OSA, policy-makers and health systems leaders have become increasingly interested in potential economic benefit from OSA treatments.[22] The most commonly prescribed and most studied treatment for OSA is continuous positive airway pressure (CPAP) therapy.[23] Although CPAP is highly effective when used as prescribed, many patients struggle to adhere to the treatment, resulting in suboptimal treatment adherence rates consistent with those seen in other chronic medical conditions.[23] In clinical practice, adherence rates vary widely. From a research perspective, CPAP adherence is typically a central determinant of outcome in randomized controlled trials (eg, references 24, 25).

To advance understanding of economic issues related to OSA treatments including CPAP, our group recently performed a comprehensive systematic review.[26] CPAP and other treatments for OSA were consistently associated with favorable economic outcomes, including reduced HCU and costs.[27] Further, 4 of 5 studies that specifically assessed CPAP adherence found adherence to be associated with favorable economic outcomes,[28–31] with the fifth study detecting no relationship between adherence and either HCU or costs.[32] However, only 2 of 17 studies meeting inclusion criteria for the systematic review examined the economic impact of OSA treatment among older adults.[33,34] Both studies suggested a positive economic effect of treatment with CPAP among older adults. A recent report by Chattre and colleagues[35] also found CPAP adherence to be associated with reduced costs among Medicare beneficiaries. However, this study was limited in that it employed an arbitrary definition of CPAP adherence, did not examine the impact of CPAP adherence on HCU, and did not report dollarized costs.

The purpose of the present study was to examine the impact of CPAP adherence on HCU among a nationally representative sample of older adult Medicare beneficiaries with multiple morbidities and OSA and cardiovascular disease. The Medicare population is of particular interest to multiple stakeholders including payers, policy makers, and health systems leaders because (1) the United States population is rapidly aging,[36] (2) Medicare is the largest payer for medical care for the elderly in the United States, and (3) Medicare is a leader in developing federal and private health policy. Our primary hypothesis was that CPAP adherence would be inversely related to HCU.

METHODS

Data source

The primary source of data for this study was a 5% random sample of Medicare administrative data created by and obtained from the Centers for Medicare & Medicaid Services Chronic Condition Data Warehouse spanning years 2008–2015.

Study design and population

After obtaining the 5% sample, we applied inclusion/exclusion criteria. Participants were Medicare beneficiaries age ≥ 65 years diagnosed with OSA and cardiovascular disease who initiated CPAP between 2009–2013. Based on Centers for Medicare & Medicaid Services policy,[37] all participants in this study would have been diagnosed with OSA based on 4% desaturations for hypopneas during breathing events. It should also be noted that we have recently found minimal impact of the difference between 3% and 4% desaturations criteria.[38] To reduce heterogeneity and assess the impact of adherence to CPAP on HCU, we focused on beneficiaries who initiated CPAP. To ensure comprehensive data capture, all study participants were required to have continuous Medicare Parts A, B, and D, with no Medicare Part C (Medicare Advantage) coverage for the 12 months before and the 24 months after the first CPAP machine charge. Thus, survival for the entire study period was required.

Cardiovascular disease

Pre-existing CVD was defined using *International Classification of Disease, Ninth Revision, Clinical Modification* (ICD-9-CM) codes and Current Procedural Technology (CPT) codes and included: Ischemic heart disease (ICD-9-CM 410.xx, 411.0, 411.1, 411.89, 412, 413.xx, 414.00–414.07, 414.1, 414.11, 414.12, 414.19, 414.2, 414.3, 414.4, 414.8, 414.9), atrial fibrillation (ICD-9-CM 427.3), heart failure (ICD-9-CM 428.×), cerebrovascular disease (ICD-9-CM 436, 435.9, 434.91, 434.11, 434.01, 433.01, 433.11, 433.21, 433.91, 433.81, V12.54, 438.1×, 438.2×, 438.3×, 438.4×, 438.5× 438.8×, 438.9), cardiac procedures (CPT 92920, 92924, 92928, 92933, 92937, 92941, 92943, 92973, 92974, 92975), and peripheral procedures (CPT 37220–37235, 37215–37218, 37236–37249, 37211–37214, 37184–37188). An inpatient or outpatient claim including any of these codes during the 12-month period prior to CPAP initiation was considered evidence of pre-existing CVD.

OSA and CPAP

All participants were required to have received at least 1 physician-assigned OSA diagnosis (ie, inpatient or outpatient claim containing ICD-9-CM codes 327.23, 780.51, 780.53, 780.57) along with 1 or more CPAP machine charges within 6 months of OSA diagnosis. CPAP machine charges were identified by a search of the durable medical equipment claims files for Healthcare Common Procedure Coding System [HCPCS] code E0601, which includes both traditional CPAP and auto-adjusting CPAP [APAP] machines. CPAP supplies (eg, masks, tubes, or cushions) were not included in our definition. The index date was the first date of a CPAP charge following a 12-month "clean" period in which no CPAP charges were observed. Because CPAP

is the most common positive airway pressure (PAP) modality, other PAP modalities (eg, bilevel PAP, adaptive servo-ventilation) were excluded.

CPAP adherence

Beginning November 1, 2008, Centers for Medicare & Medicaid Services implemented objective adherence criteria required for reimbursement of PAP (ie, ≥ 4 h of CPAP on 70% of nights, or 21 days in a consecutive 30-day period within the first 90 days of CPAP initiation). Thus, because CPAP machines are billed in 13 equal monthly payments during a "rent-to-own" period, we utilized the number of CPAP machine charges as a proxy for CPAP adherence and categorized individuals as low adherers (< 4 charges), partial adherers (4–12 charges), and high adherers (> 12 charges).

HCU and costs

HCU was captured as monthly counts of claims over the entire 36-month study period (ie, 12 months before and 24 months following first CPAP charge). We categorized HCU by point-of-service (inpatient, emergency department, outpatient, prescriptions) using information available on the claims.

Data analysis

Distributions and frequencies of all variables were assessed. We tested bivariate associations between baseline characteristics and CPAP adherence group using chi-square goodness of fit and one-way analysis of variance.

Baseline HCU may differ between low adherers and high adherers in what has been referred to as the "healthy-user effect."[39] To account for these differences, we employed a quasi-experimental approach. Specifically, we compared monthly counts of HCU after initiation of CPAP to monthly counts of HCU before CPAP initiation within each CPAP adherence group. Next, we compared these after-before comparisons across CPAP adherence groups. To accommodate the highly skewed observed distribution of HCU counts, we modeled HCU using generalized linear models with a negative binomial distribution and a log link. An interaction term between CPAP adherence group and pre-/post-CPAP initiation status was included to estimate changes in rates of HCU post-CPAP initiation, with < 4 CPAP charges as the reference category. We first modeled the unadjusted association. Next, we built our model for inpatient HCU by adding potential confounding variables as determined by a $P < .1$ in bivariate analysis and retaining those whose P-value remained < .05. We used these variables for all models. We checked the parallel trends assumption of segmented time series graphically. Rate ratios and 95% confidence intervals were reported.

Analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC) . This study was approved by the Institutional Review Board of the University of Maryland, Baltimore.

RESULTS

Participants

The final sample included 1,921 beneficiaries aged ≥ 65 years and diagnosed with CVD and OSA who subsequently received at least 1 CPAP machine charge between 2009–2013. The majority of the sample fell into the high adherence group (n = 1,308 [68.1%]), followed by low adherence (n = 377 (19.6%) and partial adherence (n = 236 [12.3%]).

Differences by PAP adherence status

The CPAP adherence groups had different demographic profiles. Low adherers were more likely to be Medicaid eligible (29.2% vs 21.6% for partial adherers and 13.7% for high adherers, $P < 0.001$). (**Table 1**). Low adherers also had a higher burden of chronic obstructive pulmonary disease (40.9% vs 33.5% [partial adherers] and 31.7% high adherers; $P = .006$) and diabetes (56.8% vs 45.8% [partial adherers] and 45.5% high adherers; $P < .001$).

Adherence status and HCU

Across all points of service, HCU counts were highest among low adherers both before and after CPAP initiation. In fully adjusted negative binomial models and relative to low adherers post-CPAP initiation, high adherers demonstrated reduced inpatient HCU (rate ratio 0.75; 95% confidence interval 0.57, 0.97) (**Table 2**). Relative to low adherers post-CPAP initiation, high adherers demonstrated reduced emergency department HCU (rate ratio 0.88; 95% confidence interval 0.70, 1.11), but this association was not statistically significant.

DISCUSSION

The most important finding from the present study among Medicare beneficiaries diagnosed with multiple morbidities and CVD and OSA and who initiated CPAP is that high CPAP adherence was associated with reduced inpatient HCU. These results add to a growing body of literature regarding economic aspects of OSA treatments and CPAP adherence among older adults and suggest several directions for future research.

Our group and others have reported that high CPAP adherence reduced risk of new cardiovascular events among individuals with multiple morbidities and OSA and pre-existing CVD.[40–46] Likewise, CPAP adherence has been shown to reduce hospital readmission rates among individuals with comorbid OSA and heart failure.[47] Other studies have reported decreased levels of inflammatory biomarkers and improved endothelial function associated with CPAP use, suggesting a potential mechanistic pathway underlying reduced CVD risk associated with CPAP.[48,49] Thus, the observed reduction in inpatient utilization may have been related to fewer CVD-related hospitalizations, suggesting a positive and beneficial role for CPAP in management of patients with multiple morbidities and OSA.

Overall, present results add to a growing body of evidence regarding economic aspects of OSA and are generally consistent with prior studies examining the impact of CPAP therapy on health care costs among older adults. In the earliest such study, Javaheri and colleagues[34] performed an administrative review of OSA and OSA treatment outcomes among Medicare beneficiaries newly diagnosed with heart failure (n = 30,719). Health care costs were found to be lowest for those tested, assigned a clinical diagnosis,

Table 1—Baseline characteristics of Medicare beneficiaries aged ≥ 65 years and diagnosed with obstructive sleep apnea (2009–2013) and cardiovascular disease with ≥ 1 CPAP charges, by CPAP adherence level (n = 1,921).

	< 4 CPAP Charges (n = 377)	4–12 CPAP Charges (n = 236)	> 12 CPAP Charges (n = 1,308)	*P*[a]
Age, years, mean (SD)	73.3 (6.0)	72.8 (5.8)	72.6 (5.5)	.08
Female sex, n (%)	163 (43.2)	101 (42.8)	537 (41.1)	.72
Race, n (%)				.12
White, non-Hispanic	326 (86.5)	204 (86.4)	1,180 (90.2)	
Black, non-Hispanic	35 (9.3)	> 20 (> 8.5)[b]	89 (6.8)	
Other	16 (4.2)	< 12 (< 5.1)[b]	39 (3.0)	
Medicaid eligible, n (%)	110 (29.2)	51 (21.6)	179 (13.7)	< .001
OREC				.16
Age	316 (83.8)	207 (87.7)	1,145 (87.5)	
Disability/ESRD	61 (16.2)	29 (12.3)	163 (12.5)	
Comorbidities, n (%)				
ADRD	39 (10.3)	15 (6.4)	99 (7.6)	.13
Anemia	205 (54.4)	112 (47.5)	631 (48.2)	.09
Asthma	79 (21.0)	38 (16.1)	212 (16.2)	.09
Atrial fibrillation	135 (35.8)	96 (40.7)	491 (37.5)	.48
Chronic kidney disease	116 (30.8)	69 (29.2)	360 (27.5)	.45
COPD	153 (40.9)	79 (33.5)	415 (31.7)	.006
Depression	110 (29.2)	50 (21.2)	295 (22.3)	.02
Diabetes	214 (56.8)	108 (45.8)	595 (45.5)	< .001
Hyperlipidemia	339 (89.9)	208 (88.1)	1,183 (90.4)	.55
Hypertension	362 (96.0)	222 (94.1)	1,218 (93.1)	.12
Ischemic heart disease	322 (85.4)	236 (79.2)	1,046 (80.0)	.05
Obesity	70 (18.6)	40 (17.0)	229 (17.5)	.85
Rheumatoid arthritis	225 (59.7)	141 (59.8)	722 (55.2)	.18
Stroke	90 (23.9)	44 (18.6)	243 (18.6)	.07

[a]*P* value from chi square goodness of fit or analysis of variance. [b]Cell size limitation. ADRD = Alzheimer disease and related dementias, CPAP = continuous positive airway pressure, COPD = chronic obstructive pulmonary disease, ERD = end-stage renal disease, OREC = original reason for entitlement code.

then treated ($6,465 per quarter [$5,758 in 2010 USD]) and highest for those not tested, assigned a clinical diagnosis, and not treated ($12,080 per quarter [$10,759 in 2010 USD]). More recently, Chhatre and colleagues[35] analyzed the impact of CPAP adherence on costs among Medicare beneficiaries. These authors reported that relative to no CPAP and partial CPAP adherence (defined as 1 or 2 CPAP machine charges), full CPAP adherence (defined as ≥ 3 CPAP charges) was associated with the smallest subsequent increase in costs, based on multiple points of service. Although our study has important methodological differences (eg, neither prior study examined HCU; we employed a rigorous definition of CPAP adherence that is based on Medicare policy) from these prior studies among older adults, our findings are consistent in suggesting economic benefit from CPAP adherence.

Our study has strengths, including a large, randomly selected sample; a study design and analytic approach that could disentangle the "healthy-user effect" from the therapeutic effect of CPAP adherence; and a novel approach to quantifying CPAP adherence based on Medicare policies in Medicare claims. These strengths lend credence to our findings.

At the same time, several limitations must be considered. First, Medicare claims do not include important clinical information such as OSA disease severity or daytime symptoms that have been shown to impact economic aspects of OSA treatments.[27] Second, we were unable to incorporate objective CPAP adherence information, instead basing our operational definition of CPAP adherence on machine charges.[50] Third, we were unable to assess alternate PAP modalities, such as bilevel PAP or adaptive-servo ventilation; these modalities should be explored in future studies. Finally, our administrative design is unable to provide evidence regarding economic end points of interest from other perspectives, such as the patient perspective (ie, out of pocket costs, quality of life), employer perspective (ie, workplace productivity), or societal perspective (ie, motor vehicle crashes).

Results of this study suggest several important directions for future research. First, much greater insight is needed into reasons for nonadherence. In the current study, significant differences were observed between beneficiaries with low adherence and high adherence, such that individuals with low adherence were

Table 2—Rate ratios (95% confidence intervals) of health care utilization during the 2 years following first CPAP charge 2009–2013 among Medicare beneficiaries aged ≥ 65 years and diagnosed with obstructive sleep apnea and cardiovascular disease (n = 1,921).

	Unadjusted	Adjusted[a]
Inpatient		
< 4 CPAP charges	Reference	Reference
4–12 CPAP charges	0.95 (0.68, 1.32)	0.84 (0.58, 1.12)
> 12 CPAP charges	0.81 (0.65, 1.00)	0.75 (0.57, 0.97)
Emergency department		
< 4 CPAP charges	Reference	Reference
4–12 CPAP charges	0.90 (0.71, 1.13)	0.91 (0.65, 1.26)
> 12 CPAP charges	0.91 (0.77, 1.08)	0.88 (0.70, 1.11)
Outpatient		
< 4 CPAP charges	Reference	Reference
4–12 CPAP charges	1.04 (0.92, 1.18)	0.97 (0.82, 1.15)
> 12 CPAP charges	1.06 (0.97, 1.15)	0.97 (0.87, 1.09)
Prescriptions		
< 4 CPAP charges	Reference	Reference
4–12 CPAP charges	1.01 (0.96, 1.07)	1.04 (0.96, 1.13)
> 12 CPAP charges	1.00 (0.96, 1.05)	1.00 (0.94, 1.05)

[a]All models adjusted for age, Medicaid eligibility, Alzheimer disease and related dementias, anemia, asthma, cataracts, chronic obstructive pulmonary disorder, depression, diabetes, hypertension, ischemic heart disease, and stroke. CPAP = continuous positive airway pressure.

more likely to be Medicaid-eligible (ie, a marker of lower socioeconomic status) and had more comorbid illness; the role of comorbidity and multimorbidity in CPAP adherence should be explored. Second, given the heterogeneous nature of OSA, identifying clinically meaningful "phenotypes" or clusters of OSA patients based on demographic and disease comorbidities, medication usage patterns, and other available data might provide valuable insight and help to identify OSA patients at risk for nonadherence and poor clinical and economic outcomes, as well as those likely to benefit from targeted treatment to increase CPAP adherence. Third, it is necessary to incorporate objective CPAP adherence data into large-scale, claims-based analyses, to evaluate the dose-response effect of CPAP on economic outcomes. Fourth, examination of the role of CPAP adherence in management of other comorbidities of OSA is needed. Finally, payers and other stakeholders require much greater understanding regarding the cost-benefit of achieving CPAP adherence, for example through intensive support, remote monitoring, or other interventions.[23] Especially in high-cost OSA subpopulations (eg, diagnosed with CVD[25]), the resulting cost-savings from CPAP adherence might justify these additional costs.

In conclusion, results of this study demonstrate that CPAP adherence is associated with reduced inpatient HCU among older adult Medicare beneficiaries with multiple morbidities and pre-existing cardiovascular disease. As health care financial models shift from volume to value,[51] financial return-on-investment will continue to increase as an important determinant of health care resource allocation. Future research should continue to explore differences between adherers and nonadherers and seek to increase CPAP adherence as a clinical, public health, and economic imperative.

ABBREVIATIONS

CPAP, continuous positive airway pressure
CVD, cardiovascular disease
ICD-9-CM, *International Classification of Disease, Ninth Revision, Clinical Modification*
OSA, obstructive sleep apnea
PAP, positive airway pressure

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