

# The Medical Cost of Undiagnosed Sleep Apnea

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**Summary:** Obstructive sleep apnea is an under-diagnosed, but common disorder with serious adverse consequences. Cost data from the year prior to the diagnosis of sleep-disordered breathing in a consecutive series of 238 cases were used to estimate the potential medical cost of undiagnosed sleep apnea and to determine the relationship between the severity of sleep-disordered breathing and the magnitude of medical costs. Among cases, mean annual medical cost prior to diagnosis was \$2720 versus \$1384 for age and gender matched controls ( $p < 0.01$ ). Regression analysis showed that the reciprocal of the apnea hypopnea index among cases was significantly related to log-transformed annual medical costs after adjusting for age, gender, and body mass index ( $p < 0.05$ ). We conclude that patients with undiagnosed sleep apnea had considerably higher medical costs than age and sex matched individuals and that the severity of sleep-disordered breathing was associated with the magnitude of medical costs. Using available data on the prevalence of undiagnosed moderate to severe sleep apnea in middle-aged adults, we estimate that untreated sleep apnea may cause \$3.4 billion in additional medical costs in the U.S. Whether medical cost savings occur with treatment of sleep apnea remains to be determined.

**Key words:** Obstructive sleep apnea; medical costs; healthcare utilization

## INTRODUCTION

OBSTRUCTIVE SLEEP APNEA (OSA) IS A SYNDROME IN WHICH sleep-disordered breathing (SDB) causes disrupted sleep. In addition to causing daytime somnolence, OSA may lead to a number of adverse consequences including cardiovascular disease, motor-vehicle accidents, and depression.<sup>1</sup> OSA is estimated to be present in 2–4% of middle-aged adults. Most of these cases are unrecognized and untreated by the health care system. Over 80% of individuals with moderate to severe OSA have not been clinically diagnosed by their health care providers.<sup>2</sup>

Given the increased morbidity and mortality associated with OSA, it is plausible that untreated OSA may have an economic burden on the health care system because of the costs of treating its adverse health effects. There is some evidence that patients diagnosed with OSA have high medical costs in the years preceding their diagnosis.<sup>3</sup> It has not been established whether these higher costs can be attributed to the presence of SDB or to the presence of coexisting characteristics such as obesity, comorbid illnesses or health

care-seeking behavior of those individuals who are diagnosed. If higher medical costs are due to the presence of SDB, effective treatment of SDB may result in medical cost savings.

In this study, medical costs in patients who were found to have clinically significant SDB were compared to controls in order to obtain an estimate of the magnitude of SDB associated costs. Also, we determined the relationship between severity of SDB and medical costs prior to diagnosis.

## METHODS

### Setting

This cross-sectional study was carried out at the Group Health Cooperative (GHC) of Puget Sound. GHC is a staff model HMO in western Washington State that provides the full spectrum of primary care and specialty services through its own salaried professional staff. The enrollee population at GHC is comparable to the surrounding community with respect to race, but it has fewer individuals at both extremes of income.<sup>4</sup> Cases included in this study sought routine care at one (East) of four regions served by this HMO. The East region had approximately 100,000 members during the period of this study. Referral to a specialty provider for sleep-related complaint was at the dis-

Accepted for publication January 1999

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Variable	Mean/%	Standard Deviation
Age	51	11.3
Sex	79% male	
BMI	33	10.2
AHI	37	34.8
Lowest % O <sub>2</sub> Saturation	76	13.7
Asthma	16%	
Coronary Artery Disease	11%	
Congestive heart failure	6%	
COPD	6%	
Cerebrovascular disease	3%	
Depression	20%	
Diabetes Mellitus	11%	
Hypertension	38%	
Hypothyroidism	7%	
Pulmonary hypertension	2%	

COPD= chronic obstructive pulmonary disease

Table 1—Descriptive information on 238 adults with a diagnosis of sleep-disordered breathing.

cretion of GHC primary care providers. The protocol for this study was approved by the Institutional Review Boards of Group Health Cooperative and University of Washington.

### Cases

The records of 358 patients evaluated for a sleep-related complaint from the East Region of GHC between 1/1/91 and 1/30/94 and subsequently referred for polysomnography were reviewed. Patients less than 18 years of age (n=2), with a prior diagnosis consistent with SDB (obstructive sleep apnea, central sleep apnea, or upper airway resistance syndrome: n=13), without continuous enrollment at

GHC between 1/31/90 and 12/31/95 (n=44), or those found not to have significant SDB (n=61) were excluded. The remaining 238 adult patients were included in our study as cases.

### Controls

A control group consisting 476 individuals with similar duration of enrollment to the cases was assembled as an age and sex matched stratified random sample from the GHC membership database.

	CDS 0-2			CDS 3-6			CDS 7-15		
	N	Mean	Median	N	Mean	Median	N	Mean	Median
Cases	109	\$1402	\$754	89	\$3145	\$1716	40	\$5367	\$3566
Controls	389	\$978	\$432	73	\$3079	\$1426	14	\$3802	\$2931

N = number of cases of controls

Mean and median refer to annual medical costs in 1996 dollars

Table 2—Mean and median medical costs for cases and controls stratified by CDS

## Data Collection

Demographic data, general medical history, clinical information from the initial visit for sleep-related complaints, as well as polysomnography results for cases, were abstracted from medical records. Data obtained from medical records included age, gender, weight, height, apnea-hypopnea index (AHI), and the presence or absence of medical conditions linked to OSA (including coronary artery disease, congestive heart failure, hypertension, pulmonary hypertension, stroke, depression) as well as other illnesses (asthma, chronic obstructive pulmonary disease, and diabetes mellitus). Variables available on controls were age, gender, Chronic Disease Score (CDS) and cost data.

## Missing Data

Data for all variables with the exception of three (AHI, height and weight) were available for each case. Data on weight were unavailable for nine cases and data on AHI were unavailable for an additional 10 cases. These 19 cases were eliminated from our regression analysis since body mass index (BMI=kg/m<sup>2</sup>) and AHI were key variables. Data on height was unavailable for 27 cases. Gender-specific mean values for height in our cohort were used for purposes of calculating BMI in these individuals.

## Chronic Disease Score

The GHC pharmacy database was used to calculate a Chronic Disease Score (CDS) for all cases and controls. The CDS is a medication use-based score that provides a measure of chronic disease status. It has been shown to be correlated with physician ratings of disease severity as well as ambulatory visits, hospitalization, and mortality.<sup>5</sup> If the initial visit occurred in the first half of the calendar year, the CDS calculated from the calendar year prior to the visit was used. If the initial visit occurred in the second half of the calendar year, the CDS from the same calendar year was used.

## Cost Data

Direct medical costs during the year prior to diagnosis were obtained from the GHC cost/ utilization database. This database has monthly cost and utilization data on over 150 categories of utilization and has been used in several published studies.<sup>6,7,8</sup> The method for assigning costs to medical care services uses the actuarially determined costs at GHC from the Utilization Management/ Cost Management Information System (UM/CMIS) database. The UM/CMIS data-collection and cost accounting methods have been fully tested, and the system is the principle source of cost information throughout GHC. A key characteristic of the system is that most overhead costs (with the exception of the costs that are unique to GHC including insurance administration and the Center for Health Studies) are fully allocated to patient care departments. Costs were adjusted to 1996 dollars using the medical care consumer price index for Seattle.

## Polysomnography

Standard polysomnographic studies were performed and scored in an accredited laboratory. Respiratory events were defined as periods of reduced airflow of 10 seconds or longer associated with at least 3% oxygen desaturation or arousal. Apneas were respiratory events with greater than 75% reduction in airflow and hypopneas were respiratory events with 25–75% reduction in airflow. Patients given a diagnosis in the clinical interpretation report that was consistent with SDB (OSA (n=230), central sleep apnea (n=1), upper airway resistance syndrome (n=7) were classified as having SDB.

## Statistical Analysis

Mean and median annual medical costs and CDS for cases were compared to those for matched controls using the non-parametric Friedman test.

For purposes of regression analysis, annual medical costs for each subject were transformed according to the

Variables added to the model	Coefficient for AHI	<i>p</i> -value	R <sup>2</sup> for model
1/AHI	-1.89	0.12	0.01
1/AHI + DEM	-2.68	0.04	0.13
1/AHI + DEM + CVD	-2.73	0.03	0.21
1/AHI + DEM + CVD + DEP	-3.17	0.01	0.22
1/AHI + DEM + CVD + DEP + OTHER	-2.35	0.05	0.34

Demographics (DEM): age, sex and BMI

Cardiovascular disease (CVD): coronary artery disease, congestive heart failure, cerebrovascular disease, hypertension and pulmonary hypertension

Depression (DEP)

Other chronic disease (OTHER): CDS, asthma, COPD, diabetes mellitus, and hyperthyroidism

Table 3—The effect of adjustment for covariates on the coefficient for 1/AHI in a linear regression model with log-transformed costs as the dependent variable.

formula:  $y_T = \log(y+1)$ , where  $y$  is an individual's expense and  $y_T$  is the transformed expense. This transformation makes the highly skewed distribution of expenses more symmetric and it stabilizes the non-constant variance in medical expenses. The "1" is added to account for individuals with no medical expenses.

For cases, the relationship between AHI and annual medical costs was explored by plotting the regression residuals of  $y_T$  after adjustment for age, sex, and BMI (on the vertical axis) versus AHI (on the horizontal axis). The appearance of this graph (costs increasing with increasing SDB up to AHI=50, then leveling off), suggested a non-linear relationship between AHI and log-costs. Based on this result, the function 1/AHI was chosen to represent the independent variable AHI in least square regression analysis.

Two way interaction terms were included in analyses if they were selected by the stepwise procedure. The statisti-

cal package S-plus was used for all statistical computations.<sup>9</sup>

## RESULTS

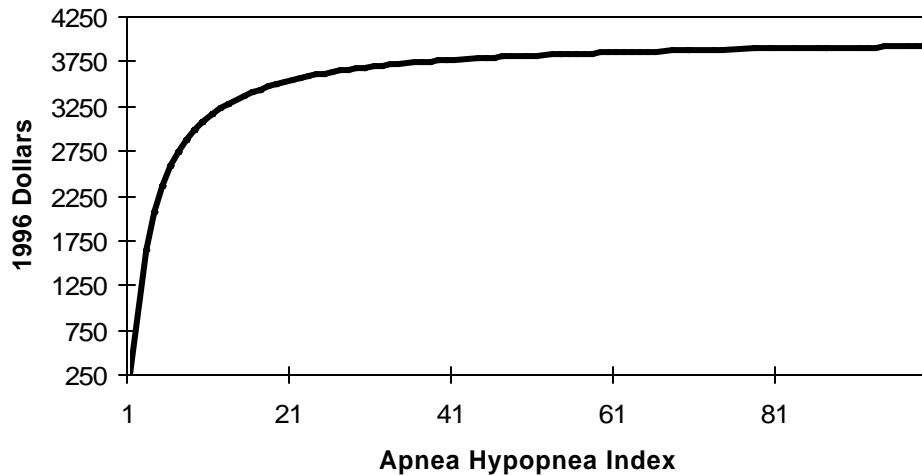
### Description of Cases

Descriptive statistics for the cases are shown in Table 1. Cases were predominantly male (79%), had a mean age of 51 years and mean BMI of 33. They had a wide range of AHI (1 to 182) with a mean value of 37 and median of 25. The most common concomitant illnesses present included hypertension (38%), depression (20%), and asthma (16%).

### Comparison of Cases and Controls

Cases had significantly higher mean and median CDS than that for matched controls ( $p < 0.01$ ). For cases, mean and median CDS were 3.3 and 3, respectively. For con-

**Figure 1. Medical Costs Versus AHI for a 51 year old Male with BMI of 33**



controls, mean and median CDS were 1.1 and 0, respectively. Cases also had higher mean and median medical costs in the year prior to diagnosis when compared to matched controls ( $p < 0.01$ ). Mean annual medical costs for cases was \$2720 compared to \$1384 for controls. Median annual costs for cases were \$1380 in comparison to \$539 for controls. Cases had higher mean costs than controls after adjustment for difference in CDS ( $p < 0.01$ ). Table 2 gives mean and median medical costs for cases and controls stratified by CDS.

#### Relationship between AHI and Costs for Cases

Table 3 gives the coefficient for  $1/AHI$ ,  $p$ -value and overall  $R^2$  in models which are unadjusted, and adjusted to include age, sex, and BMI and variables for chronic illnesses. The coefficient for  $1/AHI$  when no other covariates were included was not statistically significant ( $p = 0.12$ ). In adjusted models  $1/AHI$  was significant ( $p = 0.01$  to  $0.05$ ). There were no significant two-way interactions involving  $1/AHI$ . Figure 1 is a plot of the predicted relationship between medical costs and AHI for a male of average age and BMI using the model, which included age, sex, and BMI.

#### DISCUSSION

Our group of cases has a gender mix, mean age, mean BMI and a prevalence of comorbid illnesses that are similar to those described in other clinic based series of patients with OSA.<sup>10</sup> Among cases, there were a wide range of values of AHI with a mean AHI that was consistent with a diagnosis of moderate to severe OSA. Based on these characteristics of the cases, our findings should be generalizable to other clinic-based populations.

#### Comparison of Medical Costs and Between Cases and Controls

We found mean medical costs for cases in the year prior to diagnosis (\$2720) were approximately twice what was seen in age and sex matched controls (\$1384). The difference in costs (\$1,336) represents an unadjusted estimate for the medical cost effects of untreated OSA. A study by Kryger and colleagues of 97 obese patients with OSA had also demonstrated that cases utilized more than twice the number of inpatient hospital days and physician claims than age and sex matched controls in the two years prior to their diagnosis.<sup>3</sup> Higher medical costs in individuals with untreated sleep apnea would be expected given the known associations between OSA and adverse medical outcomes.<sup>11</sup> If the relationship between OSA and cardiovascular illnesses and depression is a causal one, the presence of untreated OSA would presumably be increasing the medical costs associated with these sequelae. In addition, non-specific symptoms caused by OSA such as fatigue could be prompting increased visits to health care providers and increased diagnostic and therapeutic interventions by health care providers.

In comparison to other previously studied patient groups at GHC, mean annual medical costs in our cases were somewhat higher than mean annual medical costs found in consecutive primary care patients with depressive and anxiety disorders (\$2,390) and considerably greater than mean annual medical costs among consecutive primary care patients without depressive and anxiety disorders (\$1,397).<sup>11</sup>

#### Sources of Confounding in the Estimation of Medical Costs Due to OSA

Two sources of confounding may have caused an overestimation of the costs of untreated OSA in both our study

and that by Kryger and colleagues. Control groups were selected at random, while cases were individuals identified as a result of their seeking health care. As a health care-seeking group, cases may have different expectations and behavior with regards to the use of health care resources and if so, this tendency would drive up medical costs. In addition, patients coming to the attention of a specialist may have a greater chronic disease burden for reasons unrelated to OSA. In our cases, CDS was significantly higher than in our controls. After adjusting for CDS, there remained a significant difference in costs between cases and controls indicating that higher chronic disease burden may not fully explain the higher costs among cases. Another study of 4972 people which examined the relationship between self-reported SDB and health care utilization was able to avoid this potential bias by surveying a random community sample. It found that subjects with breathing pauses during sleep were more likely to have consulted a doctor within the past 12 months than those without (81.0% Vs 60.8%).<sup>12</sup> Thirty one percent of subjects reporting breathing pauses had sought medical care six or more times in the past year compared with 12% of snorers who did not report breathing pauses.

The second potential source of confounding in our study was the high prevalence of obesity among cases which may have increased medical costs for reasons unrelated to OSA. Although our cases had a lower mean BMI than cases in the study by Kryger et al.(33 versus 43), it was considerably greater than normal (20-25 kg/m<sup>2</sup>). Unfortunately we did not have measurements of BMI in our controls to allow statistical adjustment for differences in this measure between cases and controls.

### **The Relationship of Medical Costs to the Severity of Sleep Disordered Breathing**

We were able to adjust for the effects of BMI, when we examined the relationship between severity of SDB and medical costs among cases. In a model which included age, sex and BMI as covariates, the coefficient of 1/AHI was statistically significant ( $p=0.04$ ), indicating that differences in severity of SDB were a factor in determining costs even after differences in age, sex, and BMI were accounted for. This finding of a dose-response relationship between SDB and medical costs supports the idea that the relationship between SDB and increased medical costs may be causal.

When categorical variables for cardiovascular illnesses and depression were included in the model, the coefficient for 1/AHI remained significant ( $p=0.03$ ). Cardiovascular diseases and depression have been linked to SDB and represent potential adverse sequelae that could be driving up medical costs in untreated SDB. The persistence of an effect of AHI on costs after including these variables has two possible explanations. It may be that there is measure-

ment error in our measures of these diseases leading to residual confounding. Alternatively, there may be causal pathways that relate SDB to medical costs that are independent of cardiovascular disease or depression. Possible examples include visits to health care providers because of complaints of fatigue or due to injuries resulting from accidents.

Our data suggest a linear relationship between AHI and costs up to a point—once that threshold is reached AHI is no longer associated with costs. This may be due to a physiological or health outcome "ceiling effect." At sufficiently high AHI, the degree of physiologic or health impairment may reach a level beyond which increases in AHI have no additional effect. For example, sleep may be disrupted to such an extent that further fragmentation may not confer additional somnolence or physiologic disturbance.

Potentially, other measures of the severity of SDB besides AHI may also be related to medical costs. Possibilities include cumulative percent of time with low oxygen saturation, arousal index, and subjective and objective measures of daytime somnolence. Unfortunately these were not available in sufficient numbers of our subjects to examine the relationship between these measures and medical costs. The shape of the curve relating medical costs and severity of SDB may be very different for these measures.

### **Implications to the U.S. Health care System**

Using the relationship we found between AHI and medical costs, we extrapolated our results to obtain an estimate of medical costs due to undiagnosed moderate to severe OSA (AHI>15 with symptoms) in middle-aged adults (age 30-60) residing in the U.S. We used mean values for age, BMI, gender, and percentage of undiagnosed moderate to severe sleep apnea cases obtained in the Wisconsin Sleep Cohort Study as well as 1990 U.S. census data to arrive at this estimate.<sup>2,13</sup> Our estimate of increased medical costs in a typical person with AHI>15 and OSA over that in a person with AHI=3, was \$1,956. Multiplying by the estimated prevalence of undiagnosed moderate to severe OSA in middle-aged individuals (1,716,000) gives a potential medical cost burden of \$3.4 billion/year attributable to untreated OSA. This figure is considerably higher than the estimate of the direct medical costs of sleep apnea in 1990 (\$275 million), made by the National Commission on Sleep Disorders Research.<sup>14</sup>

These calculations have several implications. First, they point out that untreated OSA may have a significant impact on total medical expenditures in the U.S. because of the large number of undiagnosed cases and the large increase in medical costs potentially attributable to untreated OSA. Second, it raises the possibility that some of the costs of treating OSA may be offset by cost savings in the medical costs of treating the adverse sequelae of OSA. Neither previously published data nor the data from our study directly

addresses this question.

One small study of 31 patients with OSA and severe cardiovascular and pulmonary disease found a significant decrease in hospitalization for these illnesses after initiation of nasal continuous positive airway pressure (nCPAP) therapy among 19 who reported regular use of nCPAP, which provides some support for the hypothesis that treating OSA in some patients may decrease the costs of its sequelae.<sup>15</sup>

A potential limitation of our calculation of the medical costs of untreated OSA is the assumption that the relationship between medical costs and AHI among our diagnosed cases is generalizable to individuals with undiagnosed OSA in the general population. Since our cases represent a subset of individuals with OSA, namely those that seek health care for or are identified by health care providers as having OSA, they may have very different patterns of health care use than individuals with undiagnosed OSA. Alternatively, they may have different physiological characteristics which interact with AHI to alter the severity of OSA produced in undiagnosed individuals. A second reason the assumption of generalizability of our results to the general population may not hold, is that our cases as members of an HMO had access to a generous amount of health care resources without incurring out of pocket expenses. Individuals in the general population without health insurance or with insurance that provides more limited coverage may not make use of health care resources as readily. Despite these limitations, this calculation provides an estimate of the potential costs of untreated OSA.

We have demonstrated that individuals with OSA had a higher chronic disease burden and medical costs in the year prior to diagnosis than age and sex matched controls. In addition, medical costs in our cases were related to the severity of SDB after adjusting for age, gender, and obesity. The question of whether the increased medical costs associated with SDB can be reduced after treatment of OSA, remains to be answered.

## ACKNOWLEDGMENTS

The authors thank Frankie Collins and Andrea Weinmann and Paul Westcoat for their assistance in data collection and management, and J. Randall Curtis MD, MPH for his careful review of the manuscript.

## GRANT SUPPORT

Data collection for this project was funded by a grant from the Group Health Foundation. Dr. Kapur was supported by training grants from the American Lung Association of Washington State and AHCPH grant# F32-HS00109 during the completion of this project.

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