The Relationship of Sleepiness and Blood Pressure to Respiratory Variables in Obstructive Sleep Apnea*

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As a follow-up to a previous assessment of complications of sleep-disturbed breathing in 265 patients, we have reevaluated measures of sleepiness and hypertension in patients with obstructive sleep apnea (OSA) (n=518), central sleep apnea (n=50), and subclinical sleep-disordered breathing (SDB) (n=107). Both subjective and objective (multiple sleep latency test [MSLT]) measures indicated that OSA patients were sleepier than those with subclinical SDB. The OSA patients weighed significantly more than the patients with central sleep apnea or subclinical SDB. They had a higher proportion of men, described more habitual sleepiness, and had a higher likelihood of feeling unrefreshed in the morning compared with the group with subclinical SDB. Among the OSA patients, there was a significant correlation between subjective and objective assessment of sleepiness, but this relationship was quantitatively very small. A forward stepwise regression analysis revealed that weight, and to a lesser degree waking time after sleep onset, could account for 65.5% of the variance in subjective sleepiness. Seventy-five percent of the variance of the mean sleep latency in the MSLT could be accounted for by the mean minimum arterial oxygen saturation in non-REM sleep and the nocturnal sleep latency. Diastolic BP was significantly higher in OSA patients compared with the patients with central sleep apnea and subclinical SDB. When covarying for weight, age, and gender, this effect lost significance. Among OSA patients taken by themselves, 98.3% of the variance in diastolic blood pressure could be accounted for by the mean minimum arterial oxygen saturation in non-REM sleep, with very small additional contributions of apnea/hypopnea index, weight, and age. In summary, among patients across a spectrum of SDB, differences in diastolic BP were primarily associated with weight, age, and gender. Among OSA patients, perhaps because of a more limited variance in weight, diastolic BP was associated with measures of SDB.

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Key words: hypertension; sleep; sleep apnea; sleep-disordered breathing; sleepiness

Obstructive sleep apnea (OSA) represents the most common diagnosis made at most sleep centers. In the last 6 years, we have prospectively gathered data on more than 1,600 new patients at a university-based sleep center, including 1,515 patients 18 years and older. Of these, 1,171 had polysomnograms, and 518 were found to have OSA. This article represents an analysis of these patients, describing their general characteristics, but also emphasizing two issues: (1) the relative interactions of age, weight, and sleep-disturbed respiration with hypertension; and (2) the relation of subjective and objective sleepiness. The former issue has been examined by a number of groups. In a large general practice, for instance, it was concluded that hypoxemia was associated by hypertension, but that this could be accounted for by cross-correlation with age, obesity, and alcohol consumption. In contrast, a community-based study has reported a link between hypertension and sleep apnea even when controlling for obesity, age, and gender. Our interest in the relation of subjective and objective sleepiness stems from the observation of the wide range of objectively measured sleepiness seen in patients with OSA and the minimal data available to indicate what factors are predictive of sleepiness, both as reported by the patient and as found by objective testing. This work represents an ongoing analysis of this population, which was presented previously when the total number for all patients with apnea and subclinical sleep-disordered breathing (SDB) was 265.

METHODS

The patients with OSA included 430 men and 58 women, with a mean (±SD) age of 48.5±12.2 years (Table 1). The polygraphic aspect of the diagnosis required the presence of at least five disor-

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AHI=apnea/hypopnea index; ANOVA=analysis of variance; CSA=central sleep apnea; LSD=least significant difference; MSLT=multiple sleep latency test; OSA=obstructive sleep apnea; SDB=sleep-disordered breathing

AHI=apnea/hypopnea index; ANOVA=analysis of variance; CSA=central sleep apnea; LSD=least significant difference; MSLT=multiple sleep latency test; OSA=obstructive sleep apnea; SDB=sleep-disordered breathing
Table 1—Demographic Characteristics and Symptoms in Patients with OSA, CSA, and Subclinical SDB

<table>
<thead>
<tr>
<th></th>
<th>OSA  n=518</th>
<th>CSA  n=50</th>
<th>Subclinical SDB  n=107</th>
<th>Significance p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>48.4±12.2</td>
<td>54.6±14.2</td>
<td>45.7±13.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Male, %</td>
<td>83.0</td>
<td>78.0</td>
<td>65.41</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weight</td>
<td>243.8±64.8</td>
<td>223.3±64.6</td>
<td>183.6±41.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Height</td>
<td>66.4±10.0</td>
<td>67.5±4.0</td>
<td>66.2±7.5</td>
<td>NS</td>
</tr>
<tr>
<td>Initial insomnia</td>
<td>1.22±1.34</td>
<td>1.48±1.6</td>
<td>1.21±1.4</td>
<td>NS</td>
</tr>
<tr>
<td>Awakenings during night</td>
<td>2.57±2.04</td>
<td>2.31±2.11</td>
<td>2.08±1.96</td>
<td>NS</td>
</tr>
<tr>
<td>Early morning awakening</td>
<td>1.81±1.78</td>
<td>1.65±1.85</td>
<td>1.63±1.80</td>
<td>NS</td>
</tr>
<tr>
<td>Sleepiness</td>
<td>2.63±2.12</td>
<td>2.26±2.15</td>
<td>1.90±1.83</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Awakens feeling not refreshed, %*</td>
<td>76</td>
<td>74</td>
<td>666</td>
<td>&lt;.05</td>
</tr>
</tbody>
</table>

*Symptom questions were rated by patients on a scale in which 1=not really a problem, and 5=a very major difficulty. All values except percentages represent mean±SD.

Differs from OSA group by p<0.05 by LSD test.

derived breathing events (apneas or hypopneas) per hour of sleep. For some purposes, the patients with OSA were contrasted with other groups from the overall sample of 1,171 patients. These included all patients who were found to have central sleep apnea (CSA), including 39 male and 11 female patients with a mean age of 54.6±14.2 years, and all those found to have subclinical SDB (70 male and 37 female patients, age 45.7±13.2 years). Apneas were defined as periods of cessation of airflow in the nasal and oral thermistors of at least 10 s duration, accompanied by arterial oxygen desaturation of at least 4%. Hypopneas were considered to be events with at least 50% decrease in airflow, accompanied by at least 4% decrease in oxygen saturation. The distinction between OSA and CSA was based on the presence or absence, respectively, of paradoxical chest and abdominal respiratory movements. Patients were considered to have OSA when more than 50% of time spent in SDB showed evidence of such paradoxical respiratory movement; patients were considered to have CSA when more than 50% of SDB did not show paradoxical movements. The clinical aspect of the diagnosis of OSA or CSA required that the patient exhibit other symptoms, including daytime sleepiness, poor sleep quality, a sense of not feeling refreshed in the morning, memory or concentration difficulty, or morning headaches. A diagnosis of subclinical SDB was made in patients with symptoms suggestive of sleep apnea, but a polygraphic recording that revealed 0.5 to 4.9 apneas or hypopneas per hour of sleep.

Details of recording techniques are found in Mendelson.4 To assess interrater reliability of sleep scoring, the practice of the laboratory was to have research assistants read the same record every 2 months. More than 95% of the records were initially scored by two research assistants. Interrater reliability was assessed on the basis of seven records of patients with OSA read by both persons: correlation analyses showed that r=0.98 for apnea/hypopnea index (AHI), r=0.99 for mean minimum arterial oxygen saturation, and r=0.96 for total sleep time.

On awakening in the morning, patients filled out a morning sleep questionnaire describing their subjective impression of the night’s sleep. They then had a multiple sleep latency test (MSLT), which consisted of polysomnographic measures during four 20-min opportunities to sleep (9 AM, 11 AM, 1 PM, 3 PM). They were instructed to “do whatever comes naturally,” that is, to neither try to fall asleep nor to try to stay awake. The mean sleep latency was calculated, and the presence or absence of REM onset sleep episodes was noted.3

In addition to data from the polysomnogram and MSLT, data were gathered from a sleep habit questionnaire,3,4 and the medical history and physical examination at the time of the first visit to the sleep center. These data were entered into a data file (dBaseIII+) on a personal computer.

Several types of statistical analyses were performed using a computer program (Statistica-W; Tulsa, Okla): (1) Pearson product moment correlations were used to examine the relationship of the mean sleep latency on the MSLT and subjective scores of sleepiness; (2) one-way analyses of variance (ANOVAs) were performed to assess continuous variables such as age or weight among patients with OSA, CSA, and subclinical SDB; when the ANOVA indicated a significant difference, a post hoc least significant difference (LSD) test was performed; (3) χ2 tests were performed to compare categorical data across diagnoses; (4) logistic regression analyses were employed to assess the contributions of respiratory variables and weight to categorical variables such as the presence or absence of a history of treatment for hypertension; and (5) forward stepwise regression analyses were performed for assessing the contribution of respiratory variables and weight to continuous measures such as BP or sleep latency on the MSLT.5 The latter method of analysis allows examination at each step of the variables incorporated into the model in previous stages. Thus, a variable that was incorporated at an earlier stage may at a later stage lose significance owing to its relationship with other variables that have already been included. This progresses until no more variables can be significantly entered or removed if not significant.

**RESULTS**

**General Characteristics**

General demographic features of the patients are found in Table 1. It can be seen that the patients with OSA weighed significantly more than the patients with CSA or subclinical SDB. They also had a higher frequency of men, described more habitual sleepiness, and had a higher likelihood of feeling unrefreshed in the morning compared with the group with subclinical SDB. The patients with CSA were significantly older than the other two groups. Frequent loud snoring was found in 95%, 90%, and 56.9% of the patients with OSA, CSA, and subclinical SDB, respectively (p<0.01); this was significantly more frequent in the patients with OSA than subclinical SDB (p<0.01 by LSD test). For all three groups, the most common reasons for presentation at the sleep center were the following, in descending order: (1) a specific request by the patient or referring physician to be evaluated for apnea; (2) daytime sleepiness; and (3) snoring. There was no significant difference in the frequency of known pulmo-
nary disorders among the three groups. An ANOVA revealed a significant difference among the three groups in the frequency of known cardiac disease (p<0.01), which was higher among the patients with CSA (30.0%) compared with the 16.4% in the patients with OSA (p<0.05 by LSD test) and 13.1% in the patients with subclinical SDB (p<0.01 by LSD test), possibly because of the older age of the CSA group. A current smoking history was found in 30.1% of the patients with OSA compared with 16% of patients with CSA (p<0.05) and 24.3% of patients with subclinical SDB (difference not significant by LSD test).

**Polysomnographic Data**

Data on sleep staging are found in Table 2. It can be seen that the patients with OSA fell asleep more quickly than the patients with subclinical SDB and had less stage 3 and stage 4 sleep and more stage 2 sleep than the patients with subclinical SDB. On the daytime MSLT, the patients with OSA had a significantly shorter mean sleep latency than the patients with subclinical SDB. Respiratory data during sleep are found in Table 3. The patients with OSA had a mean AHI of 53.5±37.6/h, which was significantly higher than that of the patients with CSA (p<0.01 by LSD test). Minimum arterial oxygen saturation in non-REM and REM sleep was significantly lower in the patients with OSA than in the other two groups.

**Subjective and Objective Measures of Sleepiness**

On the sleep habit questionnaire, the patients with OSA, CSA, and subclinical SDB reported sleepiness scores of 2.63±2.12, 2.26±2.15, and 1.90±1.83, respectively (ANOVA df=2, 2.672; F=6.089460; p<0.01), on a scale in which 1=not really a problem and 5=very major difficulty. An objective measure of sleepiness, the mean sleep latency on the MSLT, was 6.6±4.8, 8.6±5.6, and 12.1±14.0 min, respectively (ANOVA df=2, F=24.38595; p<0.001), indicating moderate sleepiness in the groups with OSA and CSA and normal wakefulness in the patients with subclinical SDB. In the patients with OSA, there was a significant negative correlation between the subjective and objective measures (r=-0.13; p<0.05), although the coefficient of determination (r^2) indicated that the proportion of common variation of the two variables is very small, only 1.6%. Forward stepwise regression analyses were performed to determine which variables were associated with subjective and objective sleepiness. The independent variables included age, weight, sleep measures (sleep latency, sleep efficiency, wake time after sleep onset, number of awakenings less than 3 min, number of awakenings longer than 3 min), and respiratory measures (AHI, mean and absolute minimum arterial oxygen saturation in non-REM and REM sleep). It was found that 64.4% of the variance in the report of subjective sleepiness could be explained by weight, with a minimal additional contribution of 1% by the wake time after sleep onset (Table 4). A stepwise regression using the same independent variables indicated that the absolute minimum oxygen saturation in non-REM sleep predicted 71% of the variance in MSLT sleep latency, with an additional small contribution of 4% by the nocturnal sleep latency (Table 5).

**Association of Sleep Apnea and BP**

One-way ANOVAs showed a significant association of diastolic BP with a diagnosis of OSA compared with subclinical SDB (df=1,594; F=6.788996; p<0.01). However, when we covaried for weight, this effect dropped only to a trend (p<0.06), and when we covaried for age, gender, and weight, there was no significant association. Among the patients with OSA alone, a forward stepwise multiple regression analysis (using age, weight, sleep latency, sleep efficiency, wake time, AHI, and mean and absolute minimum arterial oxygen saturat-
tions in non-REM and REM sleep as independent variables) indicated that 97.7% of the variance in diastolic BP was predicted by the mean minimum arterial oxygen desaturation in non-REM sleep, with small additional contributions (<1% each) of the AHI, weight, and age (Table 6). In a separate analysis, diastolic BP was treated as the dependent variable, and only the two measures of age and weight were treated as independent variables: it was found that weight accounted for 92.7% of the variance in diastolic BP, with an additional 4% contribution by age. Thus, age and weight were indeed highly predictive of diastolic BP when examined by themselves, but when placed in the context of a much larger group of independent variables, including measures of oxygen desaturation, were no longer significant. A forward stepwise regression analysis for systolic BP also showed that the single greatest predictor was the mean minimum oxygen saturation during non-REM sleep (Table 7).

**Association of History of Hypertension and OSA**

In a group including the patients with both OSA and subclinical SDB, a logistic regression found that the AHI and measures of desaturation (mean and minimum saturation in non-REM and REM sleep) could explain less than 1% of the variance in whether there was a history of treatment for hypertension. A logistic regression analysis of only the patients with OSA also found little relationship between a history of treatment for hypertension and variables, including age, weight, sleep efficiency, sleep latency, AHI, and mean or minimum arterial oxygen desaturation.

**DISCUSSION**

The association of adult OSA and hypertension is a complex issue that continues to be of increasing interest. Both are common illnesses; a recent review of the literature through 1993 estimates a prevalence of primary hypertension in 20% of middle-aged men, while sleep apnea may occur in 2% of women and 4% of men in the working population. Up to 30% of middle-aged men may have occult sleep apnea. A random sample of 603 employed men and women has documented the association of obesity and apneic activity, and longstanding literature notes the association of obesity and hypertension. Whether sleep-disturbed respiration is associated with hypertension independently of obesity remains a crucial question. Some studies, such as that of Hla et al in a community-based nonpatient population, and that of Strohl et al in a group of male patients evaluated for possible sleep apnea, have reported an association of measures of sleep-disturbed respiration and hypertension, independent of measures of obesity. Our analysis of diastolic BP and of a history of treatment for hypertension suggests several conclusions. When we compared patients with OSA and subclinical SDB, there was, not surprisingly, a significant difference in diastolic BP (p < 0.01); when we controlled for weight, this effect dropped to a trend (p < 0.06), and disappeared completely when covarying for age, gender, and weight. Among patients with OSA, a forward stepwise regression could account for 97.7% of the variance in diastolic BP on the basis of mean minimum arterial oxygen saturation in non-REM sleep, with only very small additional contributions of AHI, weight, and age. It should be noted, however, that AHI, mean saturation in non-REM sleep, and weight are highly intercorrelated (Fig 1). We conclude that when examining the relative contributions of age, weight, and respiratory variables to diastolic BP, the key issue is the population being examined. When looking at patients with a wide range of respiratory performance during sleep (including both subclinical SDB and OSA), a close association with age and weight appear to account for the association of OSA and increased diastolic BP. In contrast, among patients with OSA alone, in whom there is less variability in age and weight, respiratory variables can account for most of the variance in diastolic BP. Even inside this group, a model using age and weight taken by themselves could account for much of the variance in diastolic BP; when they were examined in the context of a series of independent variables, however, age and weight were less closely associated to diastolic BP than were a...
measure of arterial oxygen desaturation and AHI.

We have also noted that, in contrast to the variety of statistically significant associations with BP as measured in our clinic, there was a very minimal association (explaining <1% of the variance) between measures of sleep-disturbed respiration and a history of having been treated for hypertension. One speculation to explain this seeming difference is that it suggests that for many such patients there is a lower than optimal level of recognizing and treating hypertension.

In summary, when examining patients with OSA and subclinical SDB combined, there was an association of increased diastolic BP with OSA, but this effect could be accounted for by weight, age, and gender. This finding is consistent with a report from a general practice population, which found that the association of nocturnal hypoxemia and hypertension was primarily due to the close association with age, obesity, and alcohol consumption. Our data are also consistent with an analysis of all patients attending a sleep disorders center, which found that diastolic BP was best predicted by male gender, age, body mass index, and AHI, in that order.9 Hla et al.2 in their study of a community-based nonpatient population who underwent 24-h ambulatory BP monitoring, found an association between hypertension and sleep apnea, independent of obesity, age, and gender. Similarly, Strohl et al.8 studying 261 male subjects evaluated for possible sleep apnea, found a significant association, independent of body mass index, of mean morning BP and the AHI. Possible differences in results may involve the differences in patient and nonpatient populations (with reference to the Hla et al2 study), in methods of measurement of BP (with reference to the Strohl et al8 study), and our examination of both sexes (with reference to the Strohl et al8 study). One feature of consistency across the studies, however, is that inside the OSA group, we found that in a forward stepwise regression model, the most potent association of diastolic BP was with measures of severity of SDB, with relatively small additional contributions of weight and age.

Our previous analysis indicated that the most robust factors contributing to the variance of the mean sleep latency on the MSLT were measures of arterial oxygen desaturation and AHI. Our current, larger, data set also suggests that a measure of desaturation (minimum saturation in non-REM sleep) is the most significant predictor. One previous study10 has concluded that measures of arousal associated with apneas and hypopneas were more closely related to the mean sleep latency on the MSLT than measures of hypoxemia. It should be noted that our work, which found a closer relationship to measures of hypoxemia, employed typical clinical measures of sleep disturbance such as sleep efficiency. It is possible that if more elaborate measures of arousals were employed, such as the "respiratory arousal index" used by Roehrs et al,10 a closer association of sleep disturbance and MSLT scores might be found. It is also noted that the respiratory arousal index used in the latter study was highly correlated with their measures of desaturation (num-

Table 4—Forward Stepwise Regression Analysis of Variables Contributing to Report of Sleepiness on the Sleep Habit Questionnaire by Patients With OSA

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression Coefficient</th>
<th>Standard Error of Regression</th>
<th>R² Change*</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.009137</td>
<td>0.000976</td>
<td>.64504</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>WASO</td>
<td>0.007753</td>
<td>0.003078</td>
<td>.010826</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>F(2,202)=192.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple</td>
<td>p²=0.65533010</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*Contribution of independent variable to variance of dependent variable (subjective sleepiness). Thus, the first independent variable (weight) accounted for 64.4% of variance of the (subjective sleepiness), while the wake time after sleep onset (WASO) contributed an additional 1%.

1Significance of a test of the null hypothesis that the effect of an individual variable (controlling for other variables in the equation) is equal to zero.

1p value for the entire equation. This is a global test, including significance of the most and least powerful independent variables.
ber of minutes and number of times of desaturations (<85%), which would be consistent with our finding that a desaturation measure best correlated with the MSLT mean sleep latency. Indeed, when a regression analysis was performed using only the number of awakenings as independent variables and the MSLT sleep latency as the dependent variable, the number of awakenings longer than 3 min accounted for 41% of the variance of the MSLT, with an additional 6% contribution by the number of awakenings less than 3 min. Thus, the number of awakenings longer than 3 min, taken by themselves, was indeed predictive of objective daytime sleepiness, but when examined in the context of a model that included many other independent variables, including measures of oxygen desaturation, the number of awakenings longer than 3 min was no longer significant.

In our previous analysis, we found no significant relationship between the subjective report of habitual sleepiness and the mean sleep latency on the MSLT.

Table 5—Forward Stepwise Regression Analysis of Variables Contributing to the Mean Sleep Latency on the MSLT

<table>
<thead>
<tr>
<th>Variable*</th>
<th>Regression Coefficient</th>
<th>SE of Regression Coefficient</th>
<th>r² Change</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean min sat NR</td>
<td>0.071438</td>
<td>0.003982</td>
<td>0.712510</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SL</td>
<td>0.058929</td>
<td>0.010905</td>
<td>0.039219</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

F(2,194)=292.1352
Multiple r²=0.750729277

*Mean min sat NR=mean minimum arterial oxygen saturation in non-REM sleep; SL=sleep latency.

Table 6—Forward Stepwise Regression Analysis of Variables Contributing to Diastolic BP in Patients With OSA*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression Coefficient</th>
<th>Standard Error of Regression Coefficient</th>
<th>r² Change</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean min. sat NR1</td>
<td>0.762717</td>
<td>0.039449</td>
<td>0.976834</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AHI</td>
<td>0.128421</td>
<td>0.016885</td>
<td>0.005650</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weight</td>
<td>0.035878</td>
<td>0.009183</td>
<td>0.000449</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age</td>
<td>0.153436</td>
<td>0.047892</td>
<td>0.000412</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

F(4,415)=6125.4
Multiple r²=0.983344499

*Descriptions of parameters used in regression equation are found in Table 4.

In the current, much larger, data set, we found a relationship that was statistically significant, but that was quantitatively very small, accounting for less than 2% of the variance. This indicates that patients with OSA are poor judges of their degree of sleepiness, and again raises the importance of cautioning patients to avoid situations in which sleepiness could be hazardous.

REFERENCES

1. Stradling JR, Crosby JH. Relation between systemic hypertension and sleep hypoxaemia or snoring: analysis in 748 men drawn from general practice. BMJ 1990; 300:75-8
6. Young T, Palta M, Dempsey J, et al. The occurrence of

Table 7—Forward Stepwise Regression Analysis of Variables Contributing to Systolic BP in Patients With OSA*

<table>
<thead>
<tr>
<th>Variable1</th>
<th>Regression Coefficient</th>
<th>Standard Error of Regression Coefficient</th>
<th>r² Change</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean min sat NR</td>
<td>2.52849</td>
<td>0.112026</td>
<td>0.977206</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Abs min sat NR</td>
<td>-1.01502</td>
<td>0.123903</td>
<td>0.003348</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

F(2,395)=9958.789
Multiple r²=0.98055292

*Descriptions of parameters used in regression equation are found in Table 4.

1 Mean min sat NR=mean minimum oxygen saturation in non-REM sleep; abs min sat NR=absolute minimum oxygen saturation in non-REM sleep.

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9 Hoffstein V. Blood pressure, snoring, obesity, and nocturnal hypoxemia. Lancet 1994; 344:643-45