Sleep Deprivation Worsens Obstructive Sleep Apnea*
Comparison Between Diurnal and Nocturnal Polysomnography

Hans E. Persson, MD, PhD; and Eva Svanborg, MD

Daytime polysomnography (DPG) has been suggested for diagnosis of obstructive sleep apnea syndrome (OSAS), because it is less expensive than whole-night polysomnography investigation (NPG). To ensure sleep during day recordings, patients are often instructed to stay awake the night preceding DPG. This procedure has been validated against NPG, and also against apnea mattress recordings combined with ear oximetry (AMO). Twenty patients with OSAS symptoms were examined with NPG and simultaneous AMO and 2 to 3 weeks later with DPG 3 to 4 h in the morning after 1 night's sleep deprivation. Median apnea-hypopnea index (AHI) of DPG was 37 (95% confidence interval [CI], 19 to 44), significantly higher than median AHI of NPG (14; 95% CI, 12 to 27), whereas median nocturnal oxygen desaturation index (ODI) (11; 95% CI, 9 to 25) did not differ significantly from median AHI of NPG. Sensitivity values for DPG increased from 81 to 100% when the criteria AHI greater than 5, greater than 10, greater than 15, and greater than 20 were used, respectively. Specificity values also increased with the AHI used as cutoff point, from 50% (AHI>5) to 75% (AHI>20). In AMO, there were one false-negative case and four nonclassifiable borderline cases. If these types of simplified tests for OSAS are used for diagnosis, the risk of both false-negative and positive results (DPG) or nonclassifiable borderline cases (AMO) must be considered. Since there was a significant increase in AHI in DPG after sleep deprivation in comparison to conventional NPG, the former procedure should not be used for staging of the disease. These results also stress the importance of advice to OSAS patients concerning regular sleeping habits.

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Key words: obstructive sleep apnea; polysomnography; sleep deprivation

O bstructive sleep apnea syndrome (OSAS) is common with an estimated prevalence of at least 1.3% in adult Swedish male population1 and even higher figures for North Americans.2 The disease's cardinal symptom, habitual snoring, has a reported prevalence of 15%. Whole-night polysomnography is the only generally accepted diagnostic examination for OSAS. This test is, however, rather laborious to perform and expensive. Therefore, it has a low availability in most countries. Simplified examinations such as daytime polysomnography (DPG)3 and static charge-sensitive bed oximetry4 have therefore been suggested. There are, however, relatively few studies of the sensitivity and specificity of different simplified diagnostic methods, even though it is currently much debated to which extent and purpose they may be used.

DPG may be performed as a nap in the afternoon. Since many patients have difficulties going to sleep in daytime, in particular in a sleep laboratory, it is often thought more efficient to conduct the investigation in the morning after a night's sleep deprivation.5-7 There are a few reports concerning the diagnostic accuracy of nap recordings. To our knowledge, only one evaluation exists of DPG after sleep deprivation.8 In this, mean apnea index (AI) was found to be almost twice as high as mean AI in nocturnal polysomnography (NPG), but not correlated to the AI in the night recordings. However, nocturnal, but not diurnal polysomnographs were recorded and scored by means of a nonvalidated, not commercially available computer software. This introduces a potential error since it is known that computer scoring may underestimate the number of apneas9 and there may also be difficulties in adequately assessing sleep, especially in subjects with disturbed sleep10,11 which would influence index values.

Since it is of principal interest to establish if sleep deprivation worsens obstructive sleep apnea (OSA), a

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comparison was made between the results of DPG after sleep deprivation and conventionally recorded, manually scored NPG. Simultaneous to NPG, respiration movement recording combined with oximetry was performed separately for further comparison of sensitivities and specificities between the different methods.

**METHODS**

Twenty consecutive patients who gave their informed consent to repeated investigation included 14 men and 6 women aged 27 to 70 years (mean age, 53.1 years) with mean body mass index of 26.2 (SD 5.1). They had all been referred from ear, nose, and throat specialists under suspicion of OSAS.

All patients first underwent NPG with simultaneous, separate oximetry-respiration movement recording. The recordings were coded so that the identity of the patient was unknown to the investigator. Within 4 weeks after this examination, all patients underwent DPG after one night's sleep deprivation in another sleep laboratory.

**Nocturnal Polysomnography (NPG)**

EEG, submental and leg electromyogram, electro-oculogram, respiratory movements by a piezoelectric crystal movement sensor (Siemens Sensor 230; Siemens Inc; Stockholm, Sweden), airflow (three-channel thermistor), body position, and ECG were recorded (on a Nihon Kohden 4217; Nihon Kohden Corp; Tokyo) for 7 to 9 h.

**Apnea Mattress Oximetry (AMO)**

Respiration and body movements were recorded by means of an apnea mattress of polyvinylidene fluoride-type (Duorec Inc; Turkey, Finland), and arterial oxygen saturation was measured continuously by ear oximetry (Biox 3760; Ohmeda; Louisville, Ky) at slow paper speed (1 cm/min).

**Diurnal Polysomnography (DPG)**

EEG, submental electromyogram, electro-oculogram, respiratory movements by a thoracic strain gauge, airflow (three-channel thermistor), and ECG were recorded (on a Nihon Kohden 4217). The patients were instructed to stay awake the whole night before the investigation. The recording was started at 8 am and lasted for 3 to 4 h.

**Scoring Criteria**

Scoring of PSG recordings was performed according to guidelines from the American EEG Society. An apnea was scored when there was a complete absence of airflow as detected by thermistors for 10 s or more, and an obstructive hypopnea was scored when there was a gradual increase in respiration movements for more than 10 s without concomitant increase in the airflow recording, and the episode ended with an arousal.

Sleep in the PSG recordings was scored according to standard criteria. Sleep time in the AMO recordings was estimated from the movement recording (absence of repeated gross body movements, even or periodic respiration movements).

In a previous study of AMO recordings, it was shown that obstructive apneas give rise to a typical, diamond-shaped pattern in AMO recordings. The time during which such periodic respiration movements prevailed was calculated for each recording and expressed as percentage of the total sleep time. The total number of oxygen desaturations of 4% or more was divided by the total sleeping time in hours to give an oxygen desaturation index (ODI), in analogy to apnea-hypopnea index (AHI). It was found that all patients with periodic respiration movement time greater than 45% and ODI greater than 6 had AHI greater than 5, whereas all patients with periodic respiration time less than 18% and ODI less than 2 had AHI less than 5. These sets of criteria were therefore adopted to define abnormality vs normality in the present study, but comparison was also made with ODI greater than 5 as criterion for abnormality of AMO recordings.

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**Table 1—Individual Sleep Characteristics in Diurnal and Nocturnal Recordings***

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>TST</th>
<th>SL</th>
<th>% REM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DPG</td>
<td>NPG</td>
<td>DPG</td>
</tr>
<tr>
<td>1</td>
<td>140</td>
<td>290</td>
<td>15</td>
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<td>270</td>
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<tr>
<td>6</td>
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<td>374</td>
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<tr>
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</tr>
<tr>
<td>11</td>
<td>60</td>
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<td>40</td>
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<tr>
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<td>365</td>
<td>10</td>
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<td>105</td>
<td>244</td>
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</tr>
<tr>
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<td>40</td>
<td>384</td>
<td>115</td>
</tr>
<tr>
<td>15</td>
<td>—</td>
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</tr>
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<td>105</td>
<td>249</td>
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</tr>
<tr>
<td>17</td>
<td>100</td>
<td>277</td>
<td>45</td>
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<td>310</td>
<td>—</td>
</tr>
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<td>19</td>
<td>105</td>
<td>368</td>
<td>45</td>
</tr>
<tr>
<td>20</td>
<td>105</td>
<td>402</td>
<td>50</td>
</tr>
</tbody>
</table>

*Total sleep time (TST) in minutes, sleep latency (SL) in minutes, and percentage REM of total sleep time (% REM).
Figure 1. Comparison between AHI from DPG and NPG in individual patients.

Statistical Analysis

The results of paired observations were tested for significant difference with the Wilcoxon signed rank test. All p values were two-tailed. Correlations between paired values were tested with the nonparametric Spearman correlation test.

RESULTS

The nocturnal recordings all showed sleep during more than 4 h (range, 244 to 475 min; mean, 337 min). All diurnal recordings except one showed sleep during 40 to 160 min (mean, 103 min). During the diurnal recording, two patients entered rapid eye movement (REM) sleep, and six entered slow-wave sleep. Individual sleep characteristics are shown in Table 1.

Inter-rater Variability

DPG recordings and AMO recordings were scored blindly by both investigators.

For DPG recordings, the mean difference in AHI was 1.4 (Dr. Hans Persson: mean AHI, 33.1; 95% confidence interval [CI], 20 to 46; and Dr. Eva Svanborg: mean AHI, 34.5; 95% CI, 22 to 47). There was no significant difference between these results, and the correlation was high (r=0.95).

For AMO recordings, the mean difference in ODI was 1.3 (HP: mean, 9.2; 95% CI, 8 to 24; and ES: mean ODI, 10.5; 95% CI, 9 to 25). Again, there was no significant difference between these results, and the correlation was high (r=0.98).

The results presented below will be the scorings of ES for NPG and AMO, and of HP for DPG.

The quantitative results from DPG, NPG, and AMO are presented in Table 2.

DPG vs NPG

Median AHI of DPG was 37 (95% CI, 19 to 44). Median AHI of NPG was 13.5 (95% CI, 12 to 27). There was a significant difference (p=0.008) between AHI values from diurnal and nocturnal investigations, but the correlation between individual values was high (Fig 1) and statistically significant (r=0.80, p<0.0001).

In NPG, 16 of the 20 patients had AHI greater than 5; 13 patients had AHI greater than 10; 9 patients had AHI greater than 15, and 8 patients had AHI greater than 20. In DPG, 13 patients had AHI greater than 5; 12 patients had AHI greater than 10; and 11 patients had AHI both greater than 15 and greater than 20 in DPG. Sensitivities and specificites for these different criteria are presented in Table 3.

One patient (case 18) failed to go to sleep during the DPG session and was scored as false-negative. Of the remaining false-negative cases, one had apneas predominantly in REM sleep, which did not occur in his DPG recording, and the other had apneas almost only in the supine position.

AMO vs DPG and NPG

Median ODI was 10.5 (95% CI, 9 to 25), which was significantly different from AHI of DPG (p=0.006), but not from AHI of NPG. Individual ODI values, however, were significantly correlated to AHI of DPG.

Table 2—Individual Results From DPG and NPG and AMO Recordings

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>DPG</th>
<th>NPG</th>
<th>AMO ODI/Periodic Respirations, %</th>
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<td>7</td>
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<td>0</td>
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</tr>
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<td>0/0</td>
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<tr>
<td>20</td>
<td>37</td>
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<td>40/92</td>
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Table 3—Sensitivity and Specificity for DPG in Comparison to NPG Investigation With Different Criteria for Abnormality

<table>
<thead>
<tr>
<th>AHI</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
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<tr>
<td>&gt;5</td>
<td>81</td>
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<tr>
<td>&gt;10</td>
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<td>&gt;15</td>
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<td>70</td>
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<tr>
<td>&gt;20</td>
<td>100</td>
<td>75</td>
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</table>
Median percentage periodic breathing time of total sleep time in the nocturnal investigation was 46.5% (95% CI, 30 to 59). Individual values were significantly correlated to ODI values \((r=0.88, p<0.0001)\), AHI of DPG \((r=0.78, p<0.0001)\), and AHI of NPG \((r=0.91, p<0.0001)\).

In AMO, 11 of the 16 patients had pathologic findings when the criteria ODI greater than 6 and greater than 45% periodic breathing time was applied. In comparison to AHI greater than 5, there were one false-negative case and four borderline cases who could not be classified according to the criteria employed. None had a false-positive result, but one patient with AHI less than 5 during NPG had a borderline result in AMO. If ODI greater than 5 was the only criterion for abnormality, 13 of 16 patients were found to have pathologic results. The difference to the bilevel criterion above, however, was that there were now three truly false-negatives cases, not borderlines. There was no false-positive result.

**Discussion**

In accordance with the previous comparison of DPG after sleep deprivation with NPG by Haraldsson et al., the present study showed that the frequency of apneas was, in average, greatly increased in DPG. In contrast to the previous study, however, there was significant correlation between DPG and NPG values for individual patients. Since such an increase of apneas has not been shown in studies of afternoon nap recordings, it is likely that sleep deprivation causes a worsening of the condition. In a study by Guilleminault and Rosekind on a small number of OSAS patients, it was found that sleep deprivation had an effect similar to alcohol in increasing the number of apneas. Sleep deprivation enhances the propensity for slow-wave sleep. Since the muscle tone decreases with the depth of sleep, it may be speculated whether the mechanism behind increasing number of apneas after sleep deprivation is increased degree of muscle relaxation in the upper airways. It has also been shown previously that sleep deprivation diminishes genioglossus muscle activity in healthy awake individuals during CO\(_2\) rebreathing.

The differences between diurnal and nocturnal results in the present study are not due to variations in scoring ability between the investigators, since this was, in fact, very small. It may be discussed whether the differences could be due to variability over time on the part of the patients. It has been shown that a considerable night-to-night variability may occur, particularly in patients with infrequent apneas. In the present study, the statistical analysis indicates that the difference in AHI between the two types of investigations is not likely to be due to chance. The difference is considerable: 48% of the patients had more than 50% higher AHI in DPG than in NPG (32% had >100% increase), whereas the opposite relationship was true in 16%. One confounding factor that we cannot exclude could be that the patients spent relatively more sleep time in the supine position during the short diurnal recording than during the night.

Sleep deprivation is, in general, not recommendable as a preparation for diagnostic PSG. The one reason to perform such a procedure would be as a provocation, since apneas might become obvious in borderline cases. However, there would be difficulties concerning the definition of OSAS, as it is currently not known whether normal subjects might develop OSAs as a result of sleep deprivation. The risk of false-positive cases must certainly be considered.
The results of this study strengthen the view that OSAS patients should be advised on the importance of regular sleeping habits. Staying up late and getting up early in the morning might turn a mild case into a sudden worsening with grave consequences.

DPG without sleep deprivation as a diagnostic procedure has been evaluated in a few studies. Scharf et al.² found a sensitivity of 60% only in a small number of known OSAS patients recorded during afternoon naps. In a large recent study, van Keimpema et al.⁷ evaluated the diagnostic accuracy of 1-h DPG. They found a sensitivity of 66% and a specificity of 88%, and concluded that 1-h DPG is not sufficient either for confirming or excluding OSAS with certainty. Sériès et al.⁸ compared 10 h of nocturnal with 5 h of diurnal recordings, with resulting 88% sensitivity and 100% specificity for AHI greater than 5 in the daytime investigation. In our experience, however, it is difficult to get patients other than those with severe sleep apnea to sleep in the daytime without previous sleep deprivation (especially for >2 h!). Surprisingly, any such difficulties are not mentioned in the report by Sériès et al.⁹ Taking economy into consideration, we suspect that the cost of several sleepless daytime recordings that have to be repeated would, on an annual basis, exceed that of conventional nocturnal investigations.

An alternative procedure is half-night PSG. This has been validated by Sanders et al.¹⁰ who found a sensitivity of 93% and a specificity of 100% if AHI greater than 5 was criterion for abnormality, and 89%/70% if AHI greater than 10 was the criterion. The negative predictive values were, however, low (63%/64%). The authors therefore concluded that a half-night recording is sufficient to reliably establish a positive diagnosis, but that a negative finding must not be regarded as conclusive. They also noted that 40% of the patients did not exhibit any REM sleep in the first half of the night. This was also the case for 90% of the diurnal recordings in the present study. This is a serious drawback if the purpose of the investigation is to establish the severity of OSAS, since many patients experience their longest apneas with the deepest desaturations during REM. From an economic point of view, it would seem that little is gained by half-night PSG, since a sleep laboratory and trained staff working night hours would still be needed.

It was found that median ODI did not differ significantly from median AHI of NPG. This is in contrast to previous results.¹⁰ When ODI greater than 5 was applied as criterion for abnormality, both sensitivity and specificity figures for the AMO investigation were acceptable. However, it is, important to stress that this is a different investigation from oximetry alone, although ODI is the chosen variable to reveal abnormality. First, the movement recording from the apnea mattress makes it possible to estimate the sleeping time with good accuracy and therefore an index value, eg. ODI, may be calculated. Secondly, the movement recording also enables the scorer to rule out movement artifacts from the oximetry. This may be the explanation why there were no false-positive AMO results in the present study. The third reason is that upper airway obstruction will be revealed as periodic respiration movements, even if the apneas/hypopneas are too short to give rise to significant desaturations. It has previously been argued that oximetry alone is not a good diagnostic tool because it has a low sensitivity for mild to moderate cases.²² We agree with that view, but wish to argue that this may be amended by addition of movement recording. In the present study, there was only one false-negative case when both oximetry and respiration movement recording were taken into diagnostic consideration. Borderline cases will be identified and may undergo further investigations for final diagnosis. With the aid of AMO investigation, it is thus possible to stage the disease.

In our opinion, shortened PSG recordings have little value. If PSG is at all ventured, it is better to perform it for a full night, as was originally suggested by Gastoût et al.²² If this is not permitted by local resources, whole-night recording of fewer but well-selected parameters has a higher probability of giving the relevant information.

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