A Limited Diagnostic Investigation for Obstructive Sleep Apnea Syndrome*  
Oximetry and Static Charge Apnea Sensitive Bed

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A simplified sleep apnea investigation consisting of combined oximetry and respiration movement monitoring was compared with conventional polysomnography. These two types of recordings were performed simultaneously during one night in 77 patients with suspected obstructive sleep apnea syndrome (OSAS). A static charge sensitive bed (SCSB) was used in the simplified recording because it provides a comfortable and reliable means of recording respiration movements. Periods of obstructive apneas gave a diamond-shaped periodic respiration movement pattern in the SCSB, usually accompanied by repetitive oxygen desaturations. The average number of desaturations ≥4 percent per sleeping hour was termed the oxygen desaturation index (ODI) and compared with the apnea index (AI). In the whole population they were well correlated (p<0.0001, R²=0.41), but in individual cases there were considerable discrepancies. Patients with periodic respiration movements <18 percent of total sleeping time and ODI <2 never had AI ≥5, whereas patients with periodic respiration >45 percent and ODI >6 always had AI ≥5. Fifty-one of the 77 patients fulfilled these criteria. A bradycardia response to apneas was absent in 29 percent of patients with AI ≥5. A combination of respiration movement and oximetry recording thus seems to give sufficient information to confirm or negate a diagnosis of OSAS in a majority of patients with clinical symptoms. In borderline patients, further investigations should be performed.

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OSAS = obstructive sleep apnea syndrome; SCSB = static charge sensitive bed; ODI = oxygen desaturation index; BCG = ballistocardiographic; AI = apnea index

Obstructive sleep apnea syndrome (OSAS) has been shown to give an increased mortality, probably because of increased morbidity due to cardiovascular diseases and stroke. There is also an increased risk of traffic accidents. It is therefore of great importance that afflicted individuals be identified and treated. It is, however, a common disease with an estimated prevalence of about 1.5 percent in the general adult male population and its cardinal symptom, habitual snoring, is even more abundant with a reported occurrence of 9 to 15 percent among Swedish, Finnish, and Italian men. Because of this, it is necessary to use screening investigations to test all the individuals under clinical suspicion of OSAS. Polysomnography is the only widely accepted diagnostic investigation for OSAS up to now, but it is rather complicated to perform and therefore expensive and has, at least in Europe, a low availability.

To reduce the cost of evaluation of a sleep apnea investigation it must be simplified so that a trained technician is not needed. It should also give stable signals of good technical quality even during whole-night recordings to make constant supervision unnecessary. The recorded parameters should therefore be limited to a mandatory minimum where the technical conditions fill these requirements.

We postulated that whole-night recordings of oxygen saturation (SaO₂) and respiration movements would give enough information to allow certain distinction between patients with unobstructed breathing and patients with distinct OSAS. Respiration movement monitoring is necessary to reveal upper airway obstruction. It has previously been shown that this may be done in a very simple and reliable way by means of a static charge sensitive bed (SCSB). This device consists of a thin mattress sensing even the tiniest movements, such as the cardiac pulse, from a person lying on it. No part of the equipment is attached to the patient's body. The signals vary in amplitude depending on the body position, but will otherwise remain stable during the whole recording session since there is no risk of artifacts because of sensor sliding, changes in electrical conductivity, etc.

Pulse oximetry is a well-established method that is also very easy to perform. In a combined recording of this type, the respiration movement pattern reveals the nature of the patient's condition, ie, whether an intermittent upper airway obstruction is present, and the oximetry reveals the severity of the condition by giving the number and levels of oxygen desaturations.
The number of transient oxygen desaturations may replace the number of cessations in airflow, apneas, which has up to now been the main diagnostic criterion. Airflow monitoring was omitted from this screening recording because it may be hard to obtain good technical quality of thermistor recordings even with constant supervision and trained staff, and pneumotachygraphy was considered too cumbersome for both patient and investigator.

To determine how the SCSB-oximetry recording compares with polysomnography, both types of investigations were carried out simultaneously in whole-night recordings of 77 patients with suspected OSAS.

**MATERIAL AND METHODS**

**Subjects**

Seventeen healthy, non-habitually snoring volunteers (nine men, eight women, aged 15 to 58 years; mean age, 36 years) underwent one night of SCSB-recording in their homes to study their respiration movement patterns. Recording of respiration movements and body movements were made on a two-channel tape recorder (Oxford Medilog). The relatives were asked to note when the subject fell asleep and woke up.

Seventy-seven patients (69 men, 8 women, aged 17 to 68 years; mean age, 49 years), whose primary complaint was socially unacceptable snoring with associated symptoms suggesting OSAS, were referred from trained otolaryngologists for one night's recording in the sleep laboratory.

The polysomnographic recordings were made on a Grass model 8-11) at paper speed of 1 cm/s. They comprised EEG, submental EMG, EOG, respiration movements by a piezoelectric crystal movement sensor (Siemens Sensor 230), airflow through both nostrils and mouth (three-channel thermistor, Nihon Kohden ZE-732A), and ECG. All recordings included in this study contained more than four hours of EEG-verified sleep.

**SCSB-oximetry recordings** were performed simultaneously (on a Graphtec Servocorder) at slow paper speed (1 cm/min) to clearly demonstrate changes in SaO2 and respiration movement patterns. Respiration and body movements were recorded by means of an SCSB (Bio-matt, Biorec Inc, Finland). This device also allows separate recording of the ballistocardiographic signals, but this was not done in the present study since a higher time resolution of the recording would then have been required.

Arterial SaO2 was measured continuously with a pulse oximeter with an earprobe (Biox III). All records were scored by the same investigator (E.S.).

**Analytical Criteria**

**Polysomnographic Recordings**: An obstructive apnea was scored when there was a fall in amplitude of the thermistor tracing to less than 50 percent of the baseline level in the preceding two minutes, if there was simultaneously a successive increase in respiration movement amplitudes.  

A record was considered pathologic if the apnea index (AI) was 5 or more.

The ECG was checked carefully in each case for bradycardia responses to apneas. A response was considered positive if there was a change of at least 9 beats per minute at the end of an apnea compared with the beginning, calculated from the difference in distances between R-peaks in the ECG of the polysomnographic recording.

**SCSB-Oximetry Recordings**: Obstructive apneas almost always appear repeatedly. The respiration movements monitored by the SCSB then form a typical, periodic diamond-shaped pattern, usually accompanied by transient oxygen desaturations (Fig 1). The time during which such periodic respiration movements prevailed was calculated for each recording and was expressed as percentage of total sleeping time. The conditions for scoring of this pattern were that the difference in amplitude between minimum and maximum in one cycle was at least 100 percent and that each sequence of
periodic breathing lasted for at least five minutes. Oxygen desaturations of 4 percent or more were considered significant.* The total number of such desaturations was divided by the sleeping time in hours, forming what we in analogy to the AI have termed the oxygen desaturation index (ODI). The nadir $SO_2$ value (the lowest recorded value during the night) was also noted for each recording.

RESULTS

In none of the recordings of the 17 normal control subjects did the diamond-shaped periodic respiration movement pattern appear.

The SCSB-oximetry and the simultaneously performed polysomnographic recordings were compared for each patient. It was found that the sleeping time could be fairly well estimated from the SCSB-trace alone, if the time during which there were indications of wakefulness (frequent body movements combined with irregular respiration movements) was deducted from the recording. The body movements during REM sleep were, as a rule, much less frequent and lower in amplitude. The SCSB-calculated sleeping time was, in the whole population, slightly overestimated compared with the polysomnographic recording. The mean difference was +16 minutes (1 SD ± 36 minutes), mainly due to the fact that some patients did not move around or breathe irregularly despite being awake.

Sequences of obstructive apneas invariably gave rise to a periodic respiration movement pattern, with peak amplitudes often rising to 300 to 400 percent of the minimum level in each cycle. As a rule, they were accompanied by transient oxygen desaturations, unless the apneas were of short duration. A periodic, diamond-shaped respiration movement pattern, however, could also occur in association with snoring (as reported by the technician) without detectable diminishments in airflow. Significant decreases in $SO_2$ were then not recorded and the peaks of the "diamonds" were usually lower than those recorded during periods of apneas.

Fifty-five of the 77 patients had an AI of ≥5 in the polysomnographic recordings and were classified as cases of OSAS. Nine of these patients exhibited periodic respiration movements with concomitant, sometimes deep, desaturations for considerable lengths of time even though apneas according to the given definition were not present in the polysomnographic recording. In these cases, the ODI far exceeded the AI. This was also the case in one additional patient who had an AI of only 2 but an ODI of 27. The remaining patients with AIs less than 5 all had ODIs less than 5.

In 39 of 55 patients classified as having OSAS, the typical bradycardia response to apneas was present, but in 16 patients there was virtually no reaction at all, even though apneas longer than 30 s were recorded in all patients. Among these patients, 11 had AIs greater than 20.

When linear regression analysis was made between AI and ODI for the 55 cases of OSAS, there was a statistically significant correlation ($R^2 = 0.41$, $p<0.0001$). The values for each individual are shown in Figure 2.

The percentage of periodic respiration time out of total sleeping time was well correlated to both AI and ODI for these 55 cases ($R^2 = 0.43$ and $R^2 = 0.64$, respectively). There were also good correlations between nadir $SO_2$ and AI/ODI ($R^2 = 0.27$ and $R^2 = 0.59$, respectively); $p = 0.0001$ in all these instances. The correlation was less between average apnea duration and AI ($R^2 = 0.22$, $p<0.0004$) and not statistically significant between average apnea duration and ODI.

To summarize the results of the comparison between the two types of recording in all 77 cases, the AI calculated from the polysomnographic recording always was 5 or more if the SCSB-oximetry recording demonstrated the following: (1) periodic, diamond-shaped respiration movements during more than 45 percent of total sleep time and, in addition, (2) ODI exceeding 6. Inversely, AI was always less than 5 if (1) periodic respiration movements were present during less than 18 percent of total sleep time and, in addition, (2) ODI was less than 2.

If the latter set of thresholds is chosen as a criterion for the SCSB-oximetry recording to be considered pathologic, all cases with AI ≥5 were found, ie, the sensitivity of the test was 100 percent in comparison with polysomnography. Seven cases were false-positives, ie, the specificity was 67 percent. If only the SCSB-result had been considered, the specificity had still been 100 percent, but eight cases had been false-positives, ie, the specificity had been 62 percent. If, lastly, ODI >2 had been the only criterion for patho-
logic findings, the sensitivity would still have been 100 percent, but 11 cases had been false-positives, i.e., the specificity would only have been 48 percent.

If, on the other hand, the higher set of thresholds (periodic respiration >45 percent, ODI >6) is chosen as a criterion for pathologic findings, the specificity was 100 percent and the sensitivity was 67 percent. It is noteworthy that all the cases answering to this criterion but 2 of 33 had AI >20. The sensitivity of the SCSB-oximetry test to detect cases with AI >20 was thus 94 percent and the specificity was 86 percent (six false positives) in comparison to polysomnography. Twenty-six (34 percent) of 77 of the cases in this study had SCSB-oximetry results that fell between the two sets of criteria.

DISCUSSION

Based on the results of comparison with polysomnography, we suggest the following criteria to be used for diagnosis of OSAS with the SCSB-oximetry type of recording: (1) If periodic respiration movements are present during less than 20 percent of estimated sleep time and, in addition, ODI is less than 2, there is no evidence of significant upper airway obstruction. (2) If periodic respiration movement exceeds 45 percent of estimated sleep time and ODI exceeds 6, the recording is pathologic, indicating OSAS.

This analytical method implies, though, that there will be a number of cases where a SCSB-oximetry recording is not conclusive. This applied to 34 percent of the population in the present study. A full polysomnographic recording may be done in such cases to ensure a diagnosis. An alternative strategy is to repeat the SCSB recording after 6 to 12 months, since OSAS tends to be a progressive disease. The second recording could be expected to give a conclusive result if the disease was in a borderline state at the time of the first recording.

To make a diagnosis of OSAS based on a recording without EEG does introduce a degree of uncertainty, since the sleep time cannot be established. However, it may be estimated if body movements and respiration patterns are taken into account. In the present investigation, there was a fair correspondence between the sleep time established from the EEG and that estimated from the SCSB-recording. Other studies where devices recording body movements have been used have also shown a good correlation between estimated and polygraphically verified sleep times.

Recording of SaO₂ only is, in our opinion, not satisfactory as a screening procedure, because (1) the sleep time cannot be estimated at all, (2) body movements often create artifacts in the SaO₂-recording that may be indistinguishable in shape from desaturations resulting from apneas, and (3) some cases of OSAS with predominantly short apneas may have few significant decreases in SaO₂ but still a large number of arousals, causing daytime somnolence. Employment of SaO₂-monitoring alone thus implies a risk of both false-negative and false-positive results. Oximetry alone had a considerably poorer specificity than SCSB in the comparison made in this study.

Since obstructive apneas give a very typical pattern of waxing-waning changes in respiration movements, it has also been suggested that SCSB-recording alone could do as a screening procedure for OSAS. It would, however, not be possible to establish a diagnosis with this method alone since it was found in this study that the periodic respiration movement pattern could occur in the absence of apneas or desaturations. However, it may be speculated whether this pattern in such cases reflects a slight degree of obstruction or a change in central respiratory drive. It has also been claimed that obstructive apneas are reliably detected with the SCSB alone, if respiration, ballistocardiographic (BCG), and body movement signals are all taken into account. However, the BCG in particular demands a high-time resolution to be interpretable, which makes this type of investigation less suitable for screening purposes. In our experience, obstructive apneas may also occur without increases in BCG amplitudes or body movements indicating arousal.

The well-known bradycardia response to apneas has been considered so typical for OSAS that ambulatory ECG-recording has been suggested as a suitable screening method. Twenty-seven percent of the patients in this study with AI greater than 20 did not show any such response. The use of this parameter alone, therefore, seems to imply a risk of missing some of the gravest cases.

In the present study, we used ODI instead of AI as a critical parameter to define OSAS. One reason for doing so was that we aimed to show the effects of apneas rather than the apneas themselves. We also postulated that the majority of apneas would create desaturations of 4 percent or more. As is shown from the comparison between AI and ODI, this holds true in general, but in individual cases, there were considerable discrepancies. Patients with predominantly short apneas had significantly higher AIs than ODIs, whereas the reverse was true for some patients who probably had partial rather than complete occlusion of the upper airways. In the latter cases, this type of limited recording revealed the problem better than a full polysomnographic recording without oximetry would have done. The former cases would, on the other hand, not have been dismissed as normal despite their low ODIs, since the SCSB revealed an obstructive breathing pattern.

It is also noteworthy that ODI was better correlated to nadir SaO₂ and percentage periodic respiration than was AI for the 55 cases classified as OSAS.
Under the conditions described, we believe it justified to characterize obstructive apneas/hypopneas in terms of oxygen desaturations and respiration movement patterns, thus making it possible to diagnose the majority of referred patients with SCSB-oximetry recording alone. This type of recording may be even more effective, if computerized analysis is performed.44

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