# Comparison of partially attended night time respiratory recordings and full polysomnography in patients with suspected sleep apnoea/ hypopnoea syndrome

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**Abstract**

***Background*** **– Laboratory full polysomnography (PSG) is considered to be the gold standard for the diagnosis of the sleep apnoea/hypopnoea syndrome (SAHS), but it is expensive and time consuming. A study was undertaken to evaluate the diagnostic usefulness of a partially attended night time respiratory recording (NTRR) and a clinical questionnaire in patients with suspected SAHS in comparison with full PSG.**

***Methods*** **– Seventy six patients (54 men) of mean (SD) age 51 (11.5) years with a body mass index of 31 (5.7) kg/m$^2$ were studied at random on two different nights with full PSG at the sleep laboratory and with NTRR on a respiratory ward. NTRR records oximetry, airflow, chest and abdominal motion. All signals were continuously displayed on a computer screen throughout the night and respiratory events were scored automatically the following morning. All patients completed a clinical questionnaire.**

***Results*** **– Mean values of the apnoea/hypopnoea index (AHI) using NTRR were lower than those obtained with full PSG (22.7 (2.4) versus 32.2 (3) events/hour) which was mainly due to underrecognition of hypopnoeas. Sensitivity and specificity of NTRR for the diagnosis of SAHS were 82% and 90%, respectively, taking as reference AHI >10 on full PSG (AHI-PSG >10). The mean (±2SD) difference in AHI between the two methods was 9.6 (range −5.4–24.6) (95% confidence interval 6.2 to 13). Symptoms of witnessed apnoeas, impotence, the overall clinical impression of a trained physician, and a neck size over 40 cm were significantly more prevalent in patients with AHI-PSG of >10, but impotence was the only clinical feature significantly more prevalent in patients with false negative compared with true negative NTRR results that helped to distinguish patients with NTRR <10 but AHI-PSG >10.**

***Conclusions*** **– NTRR is a helpful and easy complementary diagnostic tool in clinical practice because it detects patients with moderate to severe SAHS reasonably well and therefore can be useful for confirming a diagnosis of SAHS and also for treatment decisions. It is suggested that patients with suspicion of SAHS should be initially studied by NTRR. When NTRR is negative, a full PSG should be performed if witnessed apnoeas, impotence, systemic hypertension, ischaemic heart disease, and a trained physician's clinical impression of SAHS are present.**

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Keywords: sleep apnoea/hypopnoea syndrome, polysomnography, night time respiratory recording.

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Recent data indicate that the sleep apnoea/hypopnoea syndrome (SAHS) is common, with 2% of middle aged women and 4% of middle aged men meeting the minimum diagnostic criteria for SAHS.[1] Morbidity and mortality are high and effective treatment is available for symptomatic patients.[2 3] Although the gold standard diagnostic procedure for SAHS is full polysomnography (PSG), most experts agree that simpler methods of diagnosing SAHS are needed to avoid having to refer all patients to specialised centres for further costly, labour intensive, and time consuming PSG. Furthermore, it has been stated that recording electrophysiological parameters is of no diagnostic value in SAHS as the condition can be as accurately defined by the apnoea/hypopnoea index (AHI) obtained per time in bed as by the AHI per time asleep.[4] Simplified night time respiratory recordings (NTRR) may therefore reduce the requirements for PSG.

A monitor within sight of trained nursing staff offers the possibility of observation of the recording on line and permits the detection of technical problems such as disconnection of thermistor or oximeter, thus reducing the rate of technically unacceptable studies. Furthermore, the sleep study may be conducted on a respiratory ward, supervised by trained nurses, and a report can be given to the patient after 20 minutes the next morning. The purpose of our study was to assess the diagnostic efficacy of a partially attended NTRR compared with full PSG in a population of patients with the clinical suspicion of SAHS.

## Methods

### PATIENTS

The study population consisted of 76 patients (54 men) of mean (SD) age 51 (11.5) years

(range 24–82) with a mean body mass index of 31 (5.7) kg/m$^2$ (range 17–48) referred to the Sleep Clinic of our hospital for evaluation of SAHS during a three month period. A physician experienced in the diagnosis and management of patients with sleep disorders interviewed and examined the patients and diagnostic sleep studies were performed at random during the following three weeks according to a randomisation table either in the sleep laboratory using full PSG or on a respiratory ward using NTRR only. This study was approved by the ethics committee of our hospital.

### QUESTIONNAIRE AND CLINICAL EXAMINATION

On the night of the NTRR study patients answered a 10 item questionnaire, including questions about snoring, headache, and tiredness on awakening in the morning, witnessed apnoeas, nocturnal choking, systemic hypertension, and ischaemic heart disease. Daytime sleepiness was categorised as falling asleep during active or passive situations or never. The oropharynx was examined and neck size was measured in all patients.

### OVERNIGHT FULL PSG

This included electroencephalographic (C4/A1, C3/A2, 02/A1, 01/A2), chin electromyographic and electro-oculographic recordings for sleep staging according to standard criteria.[5] Arterial oxygen saturation ($Sao_2$) was measured continuously with a finger probe using a pulse oximeter (504 Critical Care System Inc, Waukesha, USA). Rib cage and abdominal motion were monitored by piezoelectric bands placed over the thorax and abdomen (Resp-Ez, Bionic, Midlothian, Virginia, USA). Airflow was assessed using a thermistor. All signals were recorded continuously on a polygraph (Nicolet 1A98, Madison, Wisconsin, USA). The technician spent 30 minutes connecting the patient to the monitoring system, three hours manually scoring the recording, and stayed with the patient all night. Respiratory events were scored as apnoeas when there was a cessation of airflow lasting 10 seconds or more and as hypopnoeas when any discernible reduction of airflow lasting 10 or more seconds was observed in association with an arousal or with a cyclical dip of oxyhaemoglobin saturation ($Sao_2$). Arousals were defined according to the scoring rules of the American Sleep Disorders Association[6] as an abrupt shift in EEG frequency which may include theta, alpha, or frequencies greater than 16 Hz, subject to various conditions. An apnoea/hypopnoea index (AHI) of >10 was considered diagnostic of SAHS.

### NIGHT TIME RESPIRATORY RECORDING (NTRR)

This was performed on a different night within three weeks of full PSG using a Densa Pneumograph (Densa Ltd, Flint, UK) which measures oronasal airflow by a thermistor and chest and abdominal motion using strain gauges. Changes in phase angle are computed using the thoracoabdominal motion signals. The pulse oximeter was the same as that used for full PSG. A body position sensor generates a signal differentiating between left and right sides and the supine position. The analogue signals were digitalised and displayed on the computer screen and stored on the computer hard disk. A trained nurse connected the patient to the monitoring system in approximately 10 minutes. The recording could be observed throughout the night on a computer screen located in front of the nurse's desk, allowing easy detection and correction of any technical abnormality. On the morning after the study stored data were automatically scored, obtaining a printed apnoea report including the number of respiratory events per hour of recording, the overnight trend in $Sao_2$, and the number of drops in phase angle per hour. This took approximately 20 minutes. Apnoea and hypopnoea were defined, respectively, as a reduction of at least 80% or 50% in airflow, both associated with a higher than 2% dip in $Sao_2$ with respect to the previous 30 seconds. This automatic analysis profile was chosen because it had provided an excellent specificity (100%) and an acceptable sensitivity (64%) in a previous study.[7] The number of reductions in phase angle between chest and abdominal waveforms per hour higher than 10 was also assessed because we have found that a reduction in the phase angle between the chest and abdominal waveforms of more than 10 per hour is a sensitive predictor of SAHS (86%), although its specificity is poor (42%).[7]

### DATA ANALYSIS

Data were expressed as mean (SE). Analysis of full PSG and NTRR was carried out by the same individuals blinded to the result of the other study. The mean AHI obtained using the NTRR (AHI-NTRR) was compared with that obtained with full PSG (AHI-PSG) using a paired $t$ test. Because the automatic analysis of the NTRR takes into account the total time of study instead of the sleep time, we also compared the results of the NTRR monitoring with the AHI obtained from full PSG, dividing the total number of respiratory events by the total time in bed (AHI-time in bed). The number of obstructive, mixed, central apnoeas and hypopnoeas, and the mean duration of the respiratory events obtained with both NTRR and full PSG were also compared.

Sensitivity, specificity, and predictive values of the NTRR were calculated, obtaining a ROC curve at different cutoff points of AHI-PSG. The kappa statistic and the Bland and Altman method[8] were used to assess the agreement between the AHI obtained from full PSG and from NTRR. The clinical decision on the patient's outcome using the AHI obtained from full PSG versus NTRR along with the clinical questionnaire was compared. In our unit, together with general measures (weight loss, sleep hygiene), the decision to institute treatment with continuous positive airway pressure (CPAP) was taken on the basis of documented

*Table 1 Mean (SE) values of AHI-NTRR and AHI-time in bed. Different mean values at different cut-off points of AHI-PSG (<10 events/h, 10–20 events/h, and >20 events/h)*

| | *AHI-PSG* | *AHI-NTRR* | *AHI-time in bed* |
|---|---|---|---|
| Mean AHI (events/h) | 32.2 (3) | 22.7 (2.4)* | 27.6 (2.5)† |
| <10 events/h | 4.3 (0.6) | 4.3 (1.1) | 3.8 (1.0) |
| 10–20 events/h | 15 (1.0) | 10.3 (2.8)* | 14.0 (1.0)† |
| >20 events/h | 52.2 (3.0) | 36.3 (3.0)* | 45.3 (2.8)*† |

AHI = apnoea/hypopnoea index; PSG = full polysomnography; NTRR = night time respiratory recordings; AHI-PSG = AHI using full PSG; AHI-NTRR = AHI using NTRR; AHI-time in bed = AHI-PSG corrected for the total time in bed.
* $p<0.001$ compared with AHI-PSG; † $p<0.001$ compared with AHI-NTRR.

*Table 2 Comparison of the mean (SE) number per hour of obstructive, mixed, and central apnoeas and hypopnoeas obtained with NTRR and with full PSG*

| | *Obstructive* | *Mixed* | *Central* | *Hypopnoeas* |
|---|---|---|---|---|
| NTRR | 7.8 (1.6) | 2.7 (0.6) | 0.66 (0.1) | 11.4 (1.6) |
| PSG | 8.9 (1.7) | 2.4 (1.1) | 0.52 (0.2) | 22 (2.5)* |

NTRR = night time respiratory recording; PSG = polysomnography.
* $p<0.001$ compared with NTRR-hypopnoeas.

*Table 3 Number of patients with apnoea/hypopnoea index (AHI) <10, 10–20, and >20 events/h after the performance of both full polysomnography (PSG) and night time respiratory recording (NTRR)*

| | *AHI-NTRR <10* | *AHI-NTRR 10–20* | *AHI-NTRR >20* |
|---|---|---|---|
| AHI-PSG <10 (n=21) | 19 | 2 | 0 |
| AHI-PSG 10–20 (n=14) | 8 | 4 | 2 |
| AHI-PSG >20 (n=41) | 2 | 8 | 31 |
| Total | 29 | 14 | 33 |

For abbreviations see table 1.

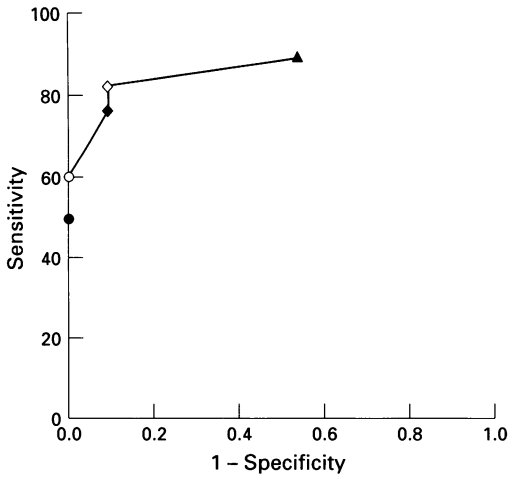


*Figure 1 Receiver operating characteristics (ROC) curve for different cut off points of the apnoea/hypopnoea index (AHI) obtained by night time respiratory recording (AHI-NTRR) in relation to the diagnosis of the sleep apnoea/hypopnoea syndrome (SAHS) by full polysomnography (AHI >10 events/hour). ▲ = AHI-NTRR >5; ◇ = AHI-NTRR >10; ◆ = AHI-NTRR >15; ○ = AHI-NTRR >20; ● = AHI-NTRR >30.*

SAHS (AHI >10) in the presence of serious clinical impairment and AHI of >30 with minor or no clinical impairment. As a secondary analysis, the value of clinical variables for predicting patients with SAHS was assessed using a $\chi^2$ test and the Fisher's exact test when appropriate. A level of $p<0.05$ was used for statistical significance.

## Results

### FULL PSG AND NTRR

As shown in table 1, the mean AHI of 22.7 (2.4) obtained with NTRR was significantly lower than the mean AHI obtained with full PSG, expressed either as mean AHI per hour of efficient sleep (AHI-PSG 32.2 (3), $p<0.001$) or corrected for the total time in bed (AHI-time in bed 27.6 (2.5), $p<0.01$). These differences were more pronounced as the AHI increased. Table 2 shows that the mean numbers of obstructive, mixed, and central apnoeas per hour measured either by NTRR or full PSG were very close, but the mean number of hypopnoeas per hour was significantly higher using full PSG. In contrast, there were no significant differences between mean duration of respiratory events measured by NTRR and by full PSG (30.5 (1.6) seconds versus 30.6 (2) seconds).

### DIAGNOSTIC VALUE OF NTRR

After the performance of full PSG 55 of the 76 patients studied (72%) were diagnosed as suffering from SAHS (>10 events/hour) and NTRR correctly identified 45 of them with 82% sensitivity, 90% specificity, and positive and negative predictive values of 96% and 65.5%, respectively, for AHI-NTRR >10/hour, which provided the best cut off to maximise sensitivity and specificity. Figure 1 shows an ROC curve plotting sensitivity and specificity of NTRR at different cut off points with respect to full PSG >10. Values of sensitivity ranged between 89% and 49% while those of specificity ranged between 46% and 100%. Agreement between both procedures was good for AHI >10 (kappa value 0.64). The Bland and Altman method showed a mean difference between AHI measured by NTRR and full PSG of 9.64 with limits of agreement (mean difference $\pm 2$ SD) of $-5.3$–24.6) and a 95% confidence interval of 6.19 to 13.1 ($p<0.05$). Table 3 shows the distribution of patients at different levels of AHI severity using NTRR compared with full PSG. Taking PSG as the "gold standard" there was a misclassification of patients at lower levels of AHI-NTRR. In contrast, values of AHI-NTRR of >20 classified patients well. Seven of the 10 false negative results using the automatic scoring of NTRR had a phase angle rate of >10. On the other hand, if the same criteria used for manual scoring of full PSG were used in patients with false negative NTRR results, the AHI increased to >10 in five patients (50%) who would therefore have been reclassified as having SAHS. The mean AHI by PSG in patients with false negative NTRR results was significantly lower than in those who were true positives (AHI 19.7 (3.5) and 48 (3.3), respectively, $p<0.001$).

### CLINICAL QUESTIONNAIRE AND PHYSICAL EXAMINATION

Table 4 shows the results of the questionnaire and physical examination according to the severity of SAHS. The presence of witnessed apnoeas, impotence, the clinical impression of the physician that patients had SAHS, and neck size over 40 cm was significantly higher

*Table 4 Results of the questionnaire and physical examination dividing the patients according to the severity of sleep apnoea*

| | AHI-PSG <10 (n=19) | AHI-PSG 10–20 (n=14) | AHI-PSG <20 (n=33) | AHI-PSG 20–50 (n=23) | AHI-PSG >50 (n=20) | AHI-PSG >20 (n=43) |
|---|---|---|---|---|---|---|
| Snoring | 88 | 100 | 95 | 83 | 100 | 100 |
| Nocturnal choking | 63 | 28 | 46 | 35 | 30 | 32 |
| Daytime sleepiness | 71 | 75 | 72 | 70 | 85 | 76 |
| Morning headache | 35 | 27 | 31 | 17 | 25 | 20 |
| Witnessed apnoeas | 38* | 57 | 46 | 70 | 85 | 78 |
| Impotence | 0* | 36 | 20 | 40 | 28 | 35 |
| Systemic hypertension | 29 | 29 | 29** | 44 | 45 | 40 |
| Ischaemic heart disease | 0 | 0 | 0** | 13 | 15 | 14 |
| Clinical impression | 29* | 50 | 38 | 56 | 80 | 68 |
| Throat examination | 44 | 17 | 29 | 32 | 70 | 51 |
| Mean (SE) neck size (cm) | 39.6 (1)* | 39.9 (0.8) | 39.7 (0.7)** | 41.5 (0.8) | 43.9 (1.1) | 42.8 (0.7) |

For abbreviations see table 1.
* $p<0.05$ for difference between AHI-PSG <10 and >10.
** $p<0.05$ for difference between AHI-PSG <20 and >20.

in patients with AHI-PSG >10 than in those with AHI-PSG <10, while systemic hypertension and ischaemic heart disease were significantly more prevalent in patients with AHI-PSG >20 compared with those with AHI-PSG <20.

ANALYSIS OF THE PATIENTS' OUTCOME

The clinical decision (CPAP, sleep hygiene, or weight loss) taken after the performance of NTRR and the clinical symptoms of patients agreed with that taken after knowing the results of full PSG in 57 patients (75%). In a further 13 patients (17%) full PSG would have been recommended because AHI-NTRR was below 10 and patients had symptoms suggesting SAHS. Only in six patients (8%) was there a disagreement, four being treated with CPAP according to full PSG but not after NTRR, and vice versa in two cases.

Using a combination of symptoms and the results of full PSG as described above, 37 patients were given treatment with nasal CPAP. When analysing the value of NTRR for detecting these patients, 30 patients (81%) would have been correctly identified, a further three (8%) would have been detected after the recommendation of the performance of a full PSG because of discordance between the negative result of NTRR and the presence of clinical symptoms, and in four patients (11%) CPAP would not have been prescribed because NTRR was negative, symptoms were few, and the practice of full PSG would not have been recommended, despite the fact that in these cases AHI-PSG was found to be higher than 30. On the other hand, two patients would have been given CPAP according to NTRR although this decision would not have been taken according to the results of full PSG.

## Discussion

This study shows that, in our clinical setting, up to 82% of patients with SAHS can be accurately diagnosed using partially attended night time respiratory recordings (NTRR) with excellent specificity. Treatment decisions can also be adequately taken with the results of NTRR.

NTRR offers some advantages as a complementary diagnostic tool in SAHS. It can be performed in the respiratory ward, attachment of all sensors requires only a few minutes, recordings can be supervised by trained nurses working at night, and the morning after a trained physician can make a visual inspection of the recordings on the screen and obtain a report with automatic processing of data in about 20 minutes.

There are only a few validation studies of other systems of simplified sleep studies. Previous studies have validated automatic scoring methods to distinguish sleep from wakefulness based on wrist activity with good results.[9] The present study is one of the few validation studies of a partially attended NTRR using airflow for defining both apnoeas and hypopnoeas and automatic scoring of the AHI. Other studies have shown good correlations between the respiratory disturbance index obtained with portable monitors recording thoracoabdominal motion or snoring and pulse oximetry and full PSG, but these have been done on small and selected populations.[10 11] Other authors have obtained a better sensitivity with a portable monitor recording airflow signals than in this study, and found no significant differences between respiratory disturbance indices from the portable monitor and that of full PSG.[12 13] However, the number of patients studied was smaller than in our study, tracings from the portable device were scored by hand, and total sleep time was estimated by means of a patient diary.

There are several explanations for the finding of a lower AHI with the NTRR monitor than with full PSG. Firstly, both studies were performed on different nights in a three week period and thus some of the differences could have been due to changes in body position, sleep hygiene, or the amount of time of efficient sleep. Although the variability of results obtained during two different nights makes little difference in patients with severe SAHS, at low AHI values there may be considerable differences.[14] This may explain why misclassification of patients at different ranges of severity according to the values of AHI was almost exclusively found when AHI-NTRR was <20. Secondly, AHI obtained with full PSG is calculated using the efficient sleep time as the denominator whereas NTRR software calculates the AHI from the total time of recording. When AHI-NTRR was compared with AHI-PSG corrected by the total time spent in bed (AHI-time in bed) the differences were reduced but still persisted. Thirdly, the mean

number per hour of obstructive, mixed, or central apnoeas showed no difference between full PSG and NTRR, but the mean number of hypopnoeas obtained with NTRR was significantly lower than with full PSG. This suggests that the main factor influencing the underestimation of the AHI using NTRR is underrecognition of hypopnoeas using an automatic scoring system. This may have been due to the different criteria applied to the manual scoring in full PSG and in the automated scoring of NTRR, which implies an underestimation of apnoeas not associated with $Sao_2$ dips, of hypopnoeas with a reduction of airflow which did not reach 50%, or of hypopnoeas associated only with arousals but not with $Sao_2$ dips. When records of the 10 patients with false negative NTRR results were scored manually with the same criteria used for full PSG (excluding arousals), the resulting AHI was >10 in 50% of cases. Also, the finding of a phase angle rate of >10 in 70% of these patients suggests that this parameter may be useful in the recognition of false negative NTRR results. This suggests that only in a few patients is the detection of arousals necessary to score hypopnoeas, and that variability at low AHI may be important in missing patients on one night because AHI was significantly lower (<20 events/hour) in cases with false negative NTRR results than in those with true positive NTRR results.

The results of a standard questionnaire showed a significantly higher prevalence of a positive clinical impression of SAHS, impotence, witnessed apnoeas, and nocturnal choking in patients with SAHS. Neck size of more than 40 cm was significantly associated with AHI-PSG >10. Impotence was the only symptom which helped to distinguish between true positive and false negative results of NTRR for AHI-PSG >10. Furthermore, the prevalence of systemic hypertension and ischaemic heart disease was significantly associated with moderate to severe SAHS (AHI-PSG >20). These results are consistent with the work of Crocker *et al*[15] who found that apnoeas observed by bed partner, hypertension, body mass index, and age were predictors of an AHI of >15. We therefore believe that patients with a clinical suspicion of SAHS – especially if symptoms of witnessed apnoeas, nocturnal choking, and impotence are present – in whom NTRR shows an AHI of <10 should be explored by means of conventional full PSG. In these patients the visual scoring of NTRR and the reductions per hour in phase angle could be useful.

In our series 37 patients were ultimately given nasal CPAP treatment and NTRR correctly identified 30 of them (81%), three more (8%) would have been detected after the recommendation of the performance of full PSG because of the discordance between the presence of symptoms suggestive of SAHS and a negative result of NTRR, and in 11% there was an incorrect treatment decision using NTRR. There was agreement on the overall clinical decision outcome with both procedures in 76% of cases, with a further 17% in whom a correct decision would have been taken after the recommendation of full PSG, and only in 8% would there have been disagreement, all of whom had minor clinical impairment and no cardiovascular risk factors with an AHI of >30 on full PSG but lower with NTRR or vice versa. Although the natural history of SAHS in patients with a high AHI and minor clinical impairment is unknown, in our unit we arbitrarily treat such patients.

In summary, NTRR accurately diagnoses moderate to severe SAHS and when combined with clinical evaluation reduces the need for PSG. Variability of SAHS on different nights in patients with mild degrees of the disease and different criteria for hypopnoea in the automatic scoring of the NTRR are likely to be the main explanations for the false negative results with NTRR. Nevertheless, the high specificity of the method is clinically useful for confirmation of the diagnosis of SAHS and for making treatment decisions. We suggest that, when a negative NTRR result is obtained, a full PSG should be performed if impotence, systemic hypertension, or ischaemic heart disease are reported or if there is a strong clinical suspicion of SAHS or another sleep disorder.

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