Quantification of sleep disordered breathing by computerized analysis of oximetry, heart rate and snoring

H. Rauscher, W. Popp, H. Zwick

ABSTRACT: Intermittent snoring and cyclic oscillations of heart rate and oxyhaemoglobin saturation (Sao₂) are characteristic features of the obstructive sleep apnoea syndrome (OSAS). Thus, overnight recordings of laryngeal sounds and heart rate by a portable device (MESAM) and of Sao₂ by oximetry are applicable to screen outpatients for the presence of OSAS. Computerized analysis for time intervals of constant heart rate and intervals between snoring sounds is used by MESAM to quantify respiratory disturbances during sleep. Rapid increases in Sao₂ during the postapnoeic hyperventilation period together with the number of desaturations are used by a new software for quantitative analysis of oximetry. To elucidate reliability of results from automatically scored MESAM and oximetry recordings, we compared the four computer calculated respiratory disturbance indices from heart rate (RDIH), snoring (RDIS), resaturations (RDIR) and desaturations (RDID) with the apnoea plus hypopnoea index (AHI) from simultaneously performed polysomnography. The study population consisted of 53 snorers with an AHI of 19.0±2.6 (median±SEM; range 0.7–87.8). Whereas both RDI’s from MESAM correlated rather weakly with the AHI from polysomnography (RDIH: r = 0.32, p<0.05; RDIS: r = 0.33, p<0.05), this correlation was much better for the RDI’s from oximetry (RDIR: r = 0.951, RDID: r = 0.93; p<0.0001). Accepting a plus/minus 30 percent difference from the AHI, the RDID classified 77% of patients correctly, the RDIR classified 53%. Thus, computerized analysis of oximetry for desaturations and rapid resaturations correlate more closely with polysomnography than those from automatic scoring of MESAM recordings.

The obstructive sleep apnoea syndrome (OSAS) causes increased morbidity and mortality [1-6], mainly from cardiovascular diseases and accidents [7, 8]. Thus, early detection of OSAS is mandatory but difficult because of the lack of specific symptoms in early stages of the disease [9]. Since it is neither possible nor appropriate to do sleep studies by polysomnography in everyone who snores or reports vague symptoms suggestive of sleep apnoea, reliable screening methods for OSAS are needed.

Recurrent apnoeas during sleep are associated with intermittent snoring and cyclic oscillations of heart rate and of oxyhaemoglobin saturation (Sao₂). Hence, tracheal sound recordings by microphones [10, 11], recordings of Sao₂ by oximetry [12], and long-term registrations of heart rate from an electrocardiograph (ECG) [11, 13] are the most common screening methods for OSAS. Each of these methods is usually conclusive about the presence or absence of OSAS. However, quantification of nocturnal respiratory disturbances is desirable as a baseline for follow-up studies in snorers with mild sleep disordered breathing, who are at risk to develop OSAS. To avoid time consuming manual scoring of the recordings [14, 15], several computer software systems for automatic analysis have been developed.

Constancy of heart rate and intervals between snoring sounds are used by MESAM (Madaus Electronics Sleep Apnoea Monitor) for quantification of respiratory disturbances during sleep [11]. Computerized analysis of oximetry is usually done by searching for desaturations [16]. However, due to the shape of the oxyhaemoglobin dissociation curve, apnoeas and hypopnoeas during sleep do not invariably cause significant falls in Sao₂ [17, 18]. Thus, computerized search for desaturations frequently misses apnoeas starting from high baseline Sao₂, as well as hypopnoeas with less pronounced desaturations. Since resumption of breathing after apnoeas or hypopnoeas is associated with a period of compensatory hyperventilation [19] causing a rapid and mostly overshooting increase in Sao₂.
computerized search for rapid resaturations is very sensitive to detect respiratory events during sleep [20]. Hence, we developed a new software which calculates the number of rapid resaturations as well as desaturations.

To clarify the value of quantitative analysis of sleep studies by this software and by MESAM for clinical routine, we compared computer calculated results of the two systems to manually scored results from simultaneously done polysomnography.

**Methods**

Oximetry for computerized analysis with our software was done by a Minolta Pulsox 7 using the finger-sensor. The Minolta Pulsox 7 calculates every second the arithmetic mean of the Sao_2_ values for the preceding seven. Thus, a file of every second actualized mean values is created, and every fifth of these values is put into the memory and stored overnight within the device. The next morning, data are transmitted to a personal computer. Our programme searches for rapid resaturations (RES), defined as increases in Sao_2_ of 3% or more within 10 s, and for desaturations (DESAT), defined as decreases in Sao_2_ of 4% or more within 40 s. To avoid multiple counting of RES and DESAT with very large changes in Sao_2_, the software contains time limits for omission of data following an increase or decrease in Sao_2_, fulfilling the criteria to be recognized as an event. Accordingly, the programme starts to search for RES from the highest value of the 15 s following the preceding RES, which should represent the end of the arousal related hyperventilation period. By analogy, the search for DESAT starts from the lowest value of the 30 s following the preceding DESAT, which should mark the end of apnoea or hypopnoea. Since the majority of apnoeas last for 15–50 s, omitting the values measured between an event found and these starting points provides high specificity without losing much sensitivity.

Two respiratory disturbance indices (RDI) are calculated from the oximetry data: the RDIR, defined as the number of RES per hour of observation, and the RDID, defined as the number of DESAT per hour of observation. For this study, observation time was set to 4 h (0.00 to 4.00 a.m.) in all of the patients.

MESAM monitors heart rate by measuring the R-R intervals from a single-lead ECG. Snoring is monitored by a subminiature microphone above the larynx. The information 'snoring' is scored if the relative power of frequencies between 50–800 cycles per second exceeds 50% of the total power. Furthermore, 'loud snoring' is scored if the output of the microphone is above a predefined threshold (1.1 mV at 1000 cycles s⁻¹). All three of these informations, i.e. heart rate, snoring and loudness, are sampled with a frequency of 1 per second and stored overnight within the recording device. Data are read out by a personal computer the next morning and analysed by the MESAM-software.

MESAM calculates a RDI from the periods of constant heart rate (RDIH) between 11–60 s. This is done by transforming the instantaneous heart rate to a percentage value of the mean heart rate for the last 5 min. All values between 90% and 109% are scored as 100% to omit variations of heart rate not exceeding plus/minus 10%. MESAM calculates a RDI from the snoring intervals between 11–60 s (RDIS). As for oximetry, these parameters were calculated for the time between 0.00 and 4.00 a.m.

Oximetry and MESAM recordings were done during a full night polysomnographical examination including continuous registration of electroencephalogram (EEG), electro-oculogram (EOG), submental electromyogram (EMG), ECG, air flow at nose and mouth (thermistors), movements of rib cage and abdomen (Respiritrace, Ambulatory monitoring, Aarlesley, NY) and Sao_2_, from the ear. For polysomnography, we used a different model oximeter (Novametrix 505) with a shorter interval for averaging primary data (2 s) to control for the rather long averaging period (7 s) of the Minolta Pulsox 7. Sleep staging was done according to standard criteria [21]. Apnoeas were defined as cessation of airflow at nose and mouth for longer than 10 s. Hypopnoeas were defined as a more than 50% reduction in the sum signal of rib cage and abdominal movements compared to the preceding 5 breaths for longer than 10 s, accompanied by a fall in Sao_2_ to 92% or lower if baseline was equal or above 94% or a fall in Sao_2_ of 3% or more if baseline was 93% or lower.

The sum of all apnoeas and hypopnoeas per hour of sleep represented the apnoea plus hypopnoea index (AHI). Two AHI's were calculated from polysomnography: the first for the real time asleep and the second for the 4 h used for the automatically calculated indices. The latter was used for correlations between the computer methods and polysomnography to avoid possible error due to uneven distribution of events over the night. The AHI for the whole night was used for comparisons between the computer calculated RDI's and polysomnography. The reason for this was, that both computer methods are intended to be used as screening methods and in screening outpatients the real time asleep is not known. Thus, calculations have to be done for an arbitrary period, but the results for this period should still reflect the AHI for the whole night.

Results are given as medians and standard error of the median (SEM) except where otherwise indicated. Correlations between computer-found events and polysomnography were calculated by Spearman's rank correlation. Comparisons between groups were done by the chi-square-test. A p-value below 0.05 was considered as statistically significant.

**Patients**

We studied 53 snorers presenting with symptoms suggestive of OSAS. Mean age of the study population was 50.2±9.9 yrs (m±sd), mean Broca-Index (= weight in kg x 100/height in cm - 100) was 117.2±2.6 (range 82–226). During the study night, the patients slept for
6.6±1.0 (mean±sd) h and had a mean \( \text{Sao}_2 \) asleep of 93.5±0.2 % (range 78.9–96.8). Awake \( \text{Sao}_2 \) in the supine position was above or equal to 95% in all of the patients. The patients' minimum \( \text{Sao}_2 \) during the night was 81.2±1.2% (range 36–93) and the mean of the 30 lowest \( \text{Sao}_2 \) values observed was 87.3±1.1% (range 42.4–95.4).

Heart rate was 72.4±3.8 beats per minute in the awake supine subjects resting for 5 min, and 67.6±2.8 during sleep. None of the patients were on medication influencing heart rate, like \( \beta \)-adrenergic antagonists, and all patients showed sinus rhythm on ECG while awake.

**Results**

Manual scoring of polysomnography revealed 7.5±2.8 apnoeas per hour of sleep with a range from 0.2–85.7. The sum of all apnoeas and hypopnoeas per hour of sleep (AHI) was 19.0±2.6 (range: 0.7–87.8) for the whole night and 21.2±3.1 for the period between 0.00 and 4.00 a.m.

Correlations of the computer calculated RDI's from oximetry with the AHI for the same period of time from polysomnography are given in figure 1. Using Spearman's rank test a highly significant correlation \((p<0.0001)\) was found for both RDI's, Spearman's \( r \) being 0.951 for the RDIR and 0.93 for the RDID.

Figure 2 shows the correlations of the computer calculated RDI's from MESAM with the AHI. The rank correlation coefficient was 0.316 for the RDIH \((p<0.05)\) and 0.329 for the RDIS \((p<0.05)\).

To elucidate clinical usefulness of the RDI's from the two screening systems, we classified our patients in two groups according to the difference between the computer calculated RDI and the AHI from polysomnography: group I, if the RDI differed less than 30% from the AHI, and group II, if the RDI differed more than 30% from the AHI. Obviously, this 30% limit was entirely arbitrary, but was assumed to represent the level of inaccuracy above which the analysis of this patient would have to be classified as wrong.

As shown in figure 3, the RDIR classified 77% of the patients within this plus/minus 30% difference from the true AHI. The corresponding numbers for the other RDI's were: 62% for the RDID, 32% for the RDIS and 23% for the RDIH.

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The abrupt resumption of ventilation during the arousal following apnoea or relevant hypopnoea is associated with loud snoring and a rapid increase in SaO₂. Therefore, the RDIR and the RDID should theoretically be equal, but we did not find this. However, there was a weak but significant correlation between the RDID and polysomnography, which is in contrast to a recent study [22] showing no significant correlation even when looking only at patients with an apnoea index above 10.

Although the automatically calculated RDI’s from oximetry correlated very closely with polysomnography, a considerable over- or underestimation of the true number of apnoeas and hypopnoeas was found in some individual patients. It should be emphasized that even the RDIR - which classified more patients within plus/minus 30% of the true AHI than all the other RDI’s - gives only a rough estimation of the amount of respiratory events in more than 20% of the patients. However, neither oximetry nor MESAM are thought as a replacement for polysomnography. The value of both methods lies in the feasibility to obtain a yes or no decision about the presence of relevant sleep apnoea by a simple, cheap method. In fact, looking at the outprints, a prompt decision about the patient’s recording being normal or abnormal was possible with both screening methods.

In conclusion, we found that computerized quantification of sleep disordered breathing correlates more closely with polysomnography when done from oximetry than from MESAM. Computerized search for desaturations and rapid resaturations classified more patients within plus/minus 30% from the polysomnographical AHI than automatic analysis of heart rate and snoring intervals.

References


**Quantification des troubles respiratoires pendant le sommeil au moyen d’une analyse computérisée de l’oxymétrie, du rythme cardiaque et du ronflement. H. Rauscher, W. Popp, H. Zwick.**

RÉSUMÉ: Le ronflement intermittent et les oscillations cycliques du rythme cardiaque et de la saturation de l’oxyhémoglobine (Sao,) sont des traits caractéristiques du syndrome d’apnée obstructive du sommeil. Dans ces conditions, l’enregistrement nocturne des sons laryngés et du rythme cardiaque au moyen d’une instrumentation portable (MESAM) et de celui de la Sao, par oxymétrie, peuvent être utilisés pour dépister le syndrome d’apnée obstructive du sommeil chez les patients. L’analyse computérisée des intervalles de temps du rythme cardiaque constant et des intervalles entre les sons de ronflement, est utilisée par le MESAM pour quantifier les troubles respiratoires pendant le sommeil. Les augmentations rapides de la Sao, au cours de l’hyperventilation post-apnéique, ainsi que le nombre de désaturations, sont employés dans un nouveau logiciel pour l’analyse quantitative de l’oxymétrie. Pour apprécier la fiabilité des résultats obtenus par les scores MESAM automatiques et les enregistrements oxymétriques, nous avons comparé les quatre indices de troubles respiratoires calculés par ordinateur à partir du rythme cardiaque (RDIH), du ronflement (RDIS), des resaturations (RDID) et des désaturations (RDID), avec l’index d’apnée plus hypopnée (AHI) obtenus à partir d’une polysomnographie simultanée.

La population étudiée comportait 53 ronfleurs dont l’AHI était de 19.0±2.6 (médiane:23; extrêmes 0.7–87.8) Alors que les deux RDI obtenus par le MESAM avaient une corrélation plutôt faible avec l’AHI polysomnographique (RDIH: r = 0.32, p<0.05; RDIS: r=0.35, p<0.05), cette corrélation était beaucoup meilleure pour les RDI obtenus par oxymétrie (RDIR: r = 0.951, RDID: r = 0.93, p<0.0001). En acceptant une différence de plus ou moins 30% autour de l’AHI, le RDIR a classifié correctement 77% des patients, le RDID 62%, le RDIH 32%, et le RDID 23%. En conclusion, les résultats de l’analyse computérisée de l’oxymétrie pour les désaturation et les resaturations rapides, sont en corrélation plus étroite avec la polysomnographie que ceux provenant d’enregistrements automatiques à partir de scores MESAM.