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

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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 (RDIIH), 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 RDIs from MESAM correlated rather weakly with the AHI from polysomnography (RDIIH: r = 0.32, p<0.05; RDIS: r = 0.33, p<0.05), this correlation was much better for the RDIs from oximetry (RDIR: r = 0.951, RDID: r = 0.93; p<0.001). Accepting a plus/minus 30 percent difference from the AHI, the RDII classified 77% of patients correctly, the RDIII classified 77% of patients correctly, the RDID 62%, the RDIS 62% and the RDII 23%. In conclusion, results from computerized analysis of oximetry for desaturations and rapid resaturations correlate more closely with polysomnography than those from automatic scoring of MESAM recordings.

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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 Sao₂ 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 read out by a personal computer the next morning. Snoring loudness, are sampled with a frequency of 1 per second into the memory and stored overnight within the device. 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.

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 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 AHI. 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 Sao₂ asleep of 93.5±0.2\% (range 78.9–96.8). Awake Sao₂ in the supine position was above or equal to 95\% in all of the patients. The patients’ minimum Sao₂ during the night was 81.2±1.2\% (range 36–93) and the mean of the 30 lowest Sao₂ 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 β-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.

Fig. 1. – Correlations of the respiratory disturbance index (RDI) from resaturations (RDIR: ■) and desaturations (RDID: □) with the apnoea plus hypopnoea index (AHI) from simultaneously done polysomnography (n=53); Spearman’s rank correlation coefficient=0.951 for RDIR (p<0.0001) and 0.93 for RDID (p<0.0001).

Fig. 2. – Correlations of the respiratory disturbance index (RDI) from oximetry with the apnoea plus hypopnoea index (AHI) from simultaneously done polysomnography (n=53); Spearman’s rank correlation coefficient=0.316 for RDIH (p<0.05) and 0.329 for RDIS (p<0.05).

Fig. 3. – Distribution of patients (n=53) in groups according to the difference between the computer calculated respiratory disturbance index (RDI) and the polysomnographical apnoea plus hypopnoea index (AHI). Group I: error<±30\%, group II: error≥±30\%.
Discussion

This study shows that computerized quantification of sleep disordered breathing from screening studies for OSAS correlates more closely with polysomnography when done from overnight SaO₂ recordings than when done from analysis of heart rate and snoring sounds. Although cyclic variation of heart rate is a characteristic feature of OSAS [13], quantification of nocturnal respiratory disturbances by the intervals of constant heart rate, as done by the MESAM software, gives rather poor results. A change in instantaneous heart rate has to exceed 10% compared with the mean value of the last 5 min to be included in the calculation of the RDIH by MESAM. From this, one would expect that the MESAM software rather underestimates the AHI, especially if baseline heart rate is high. In fact, this was true in some patients, but in the majority of patients the RDIH rather overestimated the AHI. Possible explanations for this could be changes in instantaneous heart rate due to premature beats not associated with sleep apnoea, as well as artifacts.

Since absence of breathing sounds is a sign directly related to apnoea, it is surprising that the RDIS calculated from the time intervals between snoring sounds correlated rather weakly with the AHI. Although all night snoring was observed in all of the patients in the sleep lab, we found some outprints of MESAM showing only short periods of snoring. Thus, technical problems like dislocation of the microphone dependent on body position appear to be the major cause for underestimation of the AHI by the RDIS. Furthermore, some OSAS patients disturb the analysis of intervals between snoring sounds by creating noise during apnoeic events. Dependent on the frequency spectrum and timing of these noises, this might result in over- as well as underestimation of the AHI by the RDIS. Since persisting breathing sounds during hypopnoeas preclude recognition of these events from intervals between snoring sounds, we calculated also the correlation of the RDIS with the pure apnoea index, but the result (r = 0.472, p<0.001) was not much better than for the AHI.

Since changes in SaO₂ are almost invariably due to changes in respiration whereas changes in heart rate and the creation of laryngeal sounds are influenced by numerous other factors, both RDI's from computerized analysis of oximetry quantified respiratory disturbances during sleep more accurately than MESAM. We found RES to be more sensitive than DESAT to detect apnoeas and hypopnoeas in patients with low AHI [20]. In patients with numerous events per hour, the RDIR and the RDID were nearly equal. Lower sensitivity of DESAT might be attributed to the limit for a desaturation to be detected by the computer being set to a 4 percent fall in SaO₂. This limit was not included in our definition of hypopnoea from polysomnography because only few hypopnoeic events do cause a desaturation exceeding 4%. Since even apnoeas do not invariably cause significant desaturations, both factors make the RDID rather underestimate the AHI.

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 RDIS should theoretically be equal, but we did not find this. However, there was a weak but significant correlation between the RDIS 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


