Hand-scoring of MESAM 4 recordings is more accurate than automatic analysis in screening for obstructive sleep apnoea

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ABSTRACT: The MESAM 4 system, developed to monitor breathing sounds, heart rate, arterial oxygen saturation (Sao₂) and body position, was proposed as a screening method for obstructive sleep apnoea (OSA). The aim of the study was to assess the accuracy of hand-scoring *versus* automatic-scoring in screening for obstructive sleep apnoea.

The study population consisted of 56 patients, 51 males, and 5 females, mean age 47±10 yrs, suspected of having obstructive sleep apnoea. Full polysomnography and MESAM 4 recordings were performed simultaneously. The apnoea+hypopnoea index was hand-scored in polysomnography and in MESAM 4. The hand-scoring in MESAM 4 was based on analysis of breathing sounds, heart rate and Sao₂ changes taken together. The automatic-scoring system of MESAM 4 calculated oxygen desaturation index, heart rate variation index and intermittent snoring index.

The diagnosis of obstructive sleep apnoea (apnoea+hypopnoea index ≥10) was established by polysomnography in 37 patients. Sensitivity and specificity of hand-scored MESAM 4 diagnosis were 100 and 63%, respectively. Sensitivity and specificity of MESAM 4 diagnosis with automatic-scoring were: from oxygen desaturation index 100 and 27%; from heart rate variation index 81 and 74%; and from intermittent snoring index 92 and 16%, respectively.

We suggest that hand-scoring of MESAM 4 is more accurate than automatic-scoring in screening for obstructive sleep apnoea.

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Despite the opinion of MILLMAN and FISHMAN [1] that "there is no adequate screening test for obstructive sleep apnoea" (OSA), developing such a method seems mandatory [2, 3]. Many methods have been proposed: analysis of snoring [4], activity monitoring [5], pulse oximetry [6], 24 h electrocardiographic (ECG) monitoring [7], spirometry [8], and vocalization [9].

Monitoring of physiological phenomena during sleep is more helpful in the recognition of OSA, than looking for signs which can be observed during wakefulness and are only indirectly connected with sleep-disordered breathing, *i.e.* nonspecific changes of the flow-volume loop or articulation of certain vowels.

Simultaneous recording of several variables should, in principle, give better results than single parameter analysis. Such a device should be characterized by its non-invasiveness (interpreted as resulting in no interruption of sleep), accuracy and high stability of recording lasting for several hours, and also its simplicity in application and scoring [10].

It seems that the MESAM 4 (Madaus Inc., Germany) fulfils these criteria. Its use was previously reported by STOOHS and GUILLEMINAULT [11]. However, in their study

only automatic analysis of recorded variables was considered. The aim of this validation study was to assess the accuracy of hand-scoring *versus* automatic-scoring of MESAM 4 in screening for OSA.

Material and methods

Patients

We studied patients who were referred to the sleep laboratory suspected of having sleep/wake disorders. They underwent general clinical examination and filled a typical sleep questionnaire, based on the Marburg questionnaire [12], in the presence of their bed-partners. The next step in the study consisted of eligible subjects complaining either of loud and irregular snoring or excessive daytime somnolence, or whose bed-partner observed apnoeic pauses during sleep.

Fifty six patients were admitted to the study, 51 males and 5 females. Their mean age was 47±10 yrs, Broca-Index 130±24% (range 86–200%), and diastolic blood pressure 95±15 mmHg.

Methods

Polysomnographic (PSG) and MESAM 4 recordings were performed simultaneously during a one night investigation, starting before 23:00 h and lasting for at least 6 h in each case.

Clinical examination, overnight monitoring and analysis of recorded data were performed by different investigators, unaware of the other results in a given subject.

MESAM 4

The MESAM 4 was constructed by Madaus Medizin Elektronik in co-operation with the Sleep Laboratory of the Philipps-University in Marburg (Germany), based on the preceding MESAM 2. Both devices were recently described [13, 14]. Briefly, the MESAM 4 (dimensions 190×135×45 mm and total weight 900 g including current supplying batteries) allowed four parameters to be monitored: breathing sounds, heart rate, arterial oxygen saturation (SaO_2) and body position. The processed data were digitally stored in a 128 kbyte memory, allowing up to 18 h of recording.

Breathing sounds were monitored through a subminiature microphone, type MCE 2000 (Conrad Electronics) which was placed on the neck, just below the larynx. Sounds defined as "snoring" or "loud snoring" were recognized by a system of filters and amplifiers based on power spectral analysis [4, 14]. If the relative power of frequencies between 100 and 800 Hz exceeded 50%, it was defined as "snoring". When the total power exceeded 1.1 mV at 1,000 Hz, it was defined as "loud snoring". The differentiation is represented by the height of the breathing sounds trace (fig.1).

Heart rate was monitored through a modified ECG lead D2 using the analysis of R-R intervals.

SaO_2 was measured with a pulse oximeter (Catalyst Co.), using a finger probe in the range 40–101% with an accuracy of $\pm 2\%$.

Body position sensor was placed on the lower part of sternum. Five positions could be recognized: supine, prone, on the left or on the right side, and standing.

The MESAM 4 was connected to a standard IBM-compatible PC to programme the start of recordings, analyse the recorded data and store them on a diskette or as a hard-copy.

Polysomnography

The PSG was performed using a computerized system SomnoStar 4100 (SensorMedics). The variables monitored during sleep were: the electroencephalogram (C3, C4, O1, O2); right and left electro-oculogram; submental electromyogram; electrocardiogram; thoracic and abdominal respiratory effort monitored by inductive plethysmography; nasal and oral airflow detected by thermistors; and SaO_2 monitored by a pulse oximeter (OxyShuttle, SensorMedics).

Scoring

Polysomnography. Sleep staging was performed according to standard criteria [15]. Breathing disorders were classified as obstructive, central or mixed, and their total number was assessed (#PSG). Apnoea was defined as cessation of nasal and oral airflow for at least 10 s [16]. Hypopnoea was defined as 50% decrease of thoracic and abdominal respiratory signal for 10 s or more [17]. Significant desaturation was defined as a fall in SaO_2 of 4% or more from the preceding stable SaO_2 when asleep [18]. Sleep and respiration were scored visually on a high resolution screen. The apnoea+hypopnoea index (AHI) was calculated from hand-scoring of polygraphic data, as a mean number of disordered breathing episodes for one hour of sleep. AHI was considered diagnostic for OSA when ≥ 10 .

Fig. 1. — An example of MESAM 4 data presented as a 10 min epoch of full-disclosure. It was obtained from a patient with severe obstructive sleep apnoea (OSA). Traces represent (from the top to the bottom): 1) breathing sounds show repetitive pauses which correspond to apnoeas, registration of "snoring" or "loud snoring" is indicated by the height of black markings; 2) heart rate (HR) calculated by R-R intervals analysis shows cyclical variation, units represent beats·min⁻¹; 3) oxygen saturation (SaO_2) shows deep and cyclical desaturations, units represent percentages; 4) body position (POS) indicates that the patient was lying on his back (Ba); left side (Le), right side (Ri), frontal position (Fr), upright position (Up).

MESAM 4. Using the MESAM software (version 3.01) installed in a PC, the following respiratory disturbance indices were automatically calculated: oxygen desaturation index (ODI), heart rate variation index (HRVI), and intermittent snoring index (ISI). ODI was calculated from the number of SaO_2 falls of 4% or more and longer than 10 s; HRVI was calculated from the number of periods of constant heart rate between 11 and 60 s; ISI was calculated from the number of intervals between two snores longer than 11 and shorter than 60 s.

Using hand-scoring of MESAM 4 data presented in 10 min full disclosure epochs (fig. 1), the number of abnormal respiratory events (#MESAM) and the hand-scored index (HSI), indicating mean frequency of respiratory events per hour of sleep, were calculated.

The heart rate trace was evaluated for calculation of the estimated sleep time (EST) according to previously proposed criteria [19]. Heart rate just before lights-out and just after lights-on was considered as wake heart rate. The first drop in heart rate after lights-out, with maintenance of a new rate, was taken as sleep onset. If heart rate increased more than 35 beats·min⁻¹ from the baseline and a short "plateau" was observed, it was considered as an arousal. If heart rate increased at least 5 beats·min⁻¹ and maintained a new rate, it was assessed as an awakening. Additionally the patient's report was used to determine periods of awakening during the night.

The criteria mentioned above [19] were also used for recognition of disordered breathing episodes from the heart rate trace. If heart rate increased at least 10 beats·min⁻¹ from the baseline and presented a "peak" (not a "plateau"), it was considered as a breathing episode. If heart rate increased less than 10 beats·min⁻¹, but also presented a clear "peak" and if it occurred in a period between two snores on breathing sounds trace, then this was also considered as an episode.

Intervals of silence of 10 s or more, appearing between "snoring" on the breathing sounds trace were considered as a disordered breathing episode. Such an episode was also considered when between "loud snoring" periods of "snoring" were recorded.

To recognize a breathing episode from the SaO_2 trace, a 4% or more fall was considered.

If the characteristic features described above were found simultaneously in at least two of the three traces, then an abnormal respiratory event was recognized.

Statistics

Significance of difference between mean values of calculated parameters between OSA and non-OSA was assessed using Student's t-test. Correlations between PSG and MESAM 4 results were calculated by simple regression test. A p-value below 0.05 was considered as statistically significant. Sensitivity and specificity were calculated according to the formulae: sensitivity=true positives/true positives+false negatives; specificity=true negatives/true negatives+false positives.

Results

Out of the 56 patients studied, 37 were diagnosed by PSG as having OSA and 19 as non-OSA. The mean AHI in OSA patients was 55±27 (range 16–118), and 2.5±2.6 in non-OSA. In only two non-OSA patients did it exceed 5 (5.7 and 8.8, respectively). There was no difference in age, body weight, diastolic blood pressure and mean SaO_2 between OSA and non-OSA subjects (table 1). Only the minimum SaO_2 was significantly lower in OSA. All PSG and MESAM 4 parameters

Table 1. – Comparison of some clinical data, overnight oxygenation and PSG and MESAM 4 results between OSA and non-OSA patients

	OSA	Non-OSA	p-value
Age yrs	46±10	49±9	NS
BI %	134±25	121±20	NS
Diastolic BP mmHg	96±15	93±15	NS
SaO_2 mean %	94.7±2	94.9±2.4	NS
SaO_2 min %	59±17	81±9	<0.001
AHI	55±27	2.5±2.6	<0.0001
#PSG	275±143	13±13	<0.0001
HSI	53±26	10±7	<0.0001
#MESAM	248±143	59±48	<0.0001
ODI	49±27	13±4	<0.0001
HRVI	27±17	6±4	<0.0001
ISI	36±17	27±13	NS

Data are presented as mean±SD. OSA: obstructive sleep apnoea; PSG: polysomnography; BI: Broca Index; BP: blood pressure; SaO_2 : arterial oxygen saturation by pulse oximetry; AHI: apnoea+hypopnoea index; #PSG: number of abnormal respiratory events in polysomnography; HSI: hand-scored index; #MESAM: number of abnormal respiratory events in MESAM 4; ODI: oxygen desaturation index; HRVI: heart rate variation index; ISI: intermittent snoring index; NS: nonsignificant.

Table 2. – Comparison and correlations of PSG and MESAM 4 results in the whole study group

PSG	MESAM 4		
	Index	Student's t-test	r
AHI (37±33)	HSI (38±29)	NS	0.95
	ODI (37±27)	NS	0.94
	HRVI (20±17)	p<0.001	0.71
	ISI (33±16)	NS	0.28
#PSG (175±158)	#MESAM (208±160)	NS	0.96
TST h (5±0.7)	EST h (5.5±0.7)	p<0.001	0.44

Data are presented as mean±SD. r: correlation coefficient; TST: total sleep time obtained from PSG; EST: estimated sleep time obtained from MESAM 4 hand-scoring. For further abbreviations see legend to table 1.

differed significantly between both groups (OSA and non-OSA) except for ISI.

Comparison of PSG and MESAM 4 parameters in the whole group of 56 patients showed no significant difference between PSG and MESAM 4 indices, except for HRVI ($p < 0.001$); there was no difference between #PSG and #MESAM but total sleep time from PSG and EST differed significantly (table 2). There were highly significant correlations of HSI and ODI with AHI and of #MESAM with #PSG ($r = 0.95$, 0.94 and 0.96 , respectively) (table 2).

The best MESAM 4 index, as regards sensitivity and specificity in diagnosing OSA, was HSI being 100 and 63%, respectively. Other indices, scored automatically, showed the following sensitivity and specificity: ODI 100 and 27%; HRVI 81 and 74%; and ISI 92 and 16%, respectively.

Discussion

We found that hand-scoring of MESAM 4 gives 100% sensitivity and 63% specificity. This result was better than any of the automatically scored indices. High sensitivity of the proposed method fulfil criteria of a good screening method to minimize the false negative results. Erroneous identification of a normal subject as being ill (false positive) is not desirable, but less important than overlooking a sick subject (false negative).

Specificity of hand-scored index was much better than any of the automatic ones. Also, PENZEL *et al.* [20], who found a very high sensitivity of hand-scoring in MESAM 4, reported relatively low specificity (81%). Nevertheless, in their material it was still much higher than the specificity of automatically scored indices.

Our findings in automatic-scoring are comparable to those obtained by STOOHS and GUILLEMINAULT [11, 19] and RAUSCHER *et al.* [21]. They support the finding that the results of automatic-scoring of heart rate and breathing sounds correlated weakly with PSG. Only STOOHS and GUILLEMINAULT [11] reported very high sensitivity and specificity of the third automatically scored index - ODI. In our study, sensitivity of ODI was 100%; however, specificity was low (27%). Specificity of a given variable depends on arbitrarily adopted cut-off points. In our study, increase of the cut-off level of AHI to 15, would improve the specificity of ODI to 87%.

There are at least three possible explanations for the unsatisfactory specificity of hand-scoring in MESAM 4. The use of thermistors for airflow detection in PSG may result in missing some events, which could be recognized by heart rate and breathing sounds. According to NETZER *et al.* [22], MESAM 4 could recognize more respiratory events than the thermistors do. The use of pneumotachography, the only one quantitative method for airflow measurement, could be a solution. Unfortunately, its effects on sleep quality limits practical use of this method [23, 24].

Another reason for misdiagnoses lies in the significant difference between total sleep time in PSG and

EST in MESAM 4, which is calculated only in approximation from the patient's log and the heart rate trace. This may lead to errors in calculation of HSI.

MESAM 4 also does not differentiate obstructive or other respiratory events [25]. However, in our study, there was no significant difference in the total number of recognized respiratory events between PSG and MESAM 4.

Despite the limitations mentioned above, the advantage of hand-scoring *versus* automatic-scoring may be seen in patient-to-patient analysis of data. Eight of our patients classified by at least two automatic indices falsely as OSA were correctly recognized by hand-scoring as non-OSA; another two who were missed by automatic-scoring were accurately classified by hand-scoring of MESAM 4 as having OSA.

Polysomnography, recognized as a diagnostic gold standard for sleep-related breathing disorders, is expensive and not sufficiently available. Thus, there is a need for a simple screening method which would, with clinically acceptable accuracy, separate OSA from non-OSA patients, reducing referrals for PSG.

MESAM 4 is a simple, relatively inexpensive, and easy to use screening device. Application of this method includes only three sensors and three electrodes, hardly interfering with patient's sleep. We have also demonstrated the sturdiness of the device by performing MESAM 4 night studies at home in over 100 out-patients with sleep disturbances. One finger probe was broken and, in less than 3% of the patients, the Sao_2 trace was unusable because of probe dislocation.

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