

MESAM 4: An Ambulatory Device for the Detection of Patients at Risk for Obstructive Sleep Apnea Syndrome (OSAS)*

Riccardo Stoohs, M.D.; and Christian Guilleminault, M.D.

A validation study was performed on the MESAM 4, a digital recording device developed to monitor oxygen saturation, heart rate (HR), snoring, and body position in order to screen subjects for obstructive sleep apnea syndrome (OSAS). MESAM 4 recordings were scored with the computer-based automatic scoring system provided with the equipment. Nocturnal polysomnography (PSG) and MESAM 4 recordings were run simultaneously on 56 subjects presenting with any type of sleep complaint, including those secondary to OSAS. Patients were assigned to one room by hospital administration and were monitored consecutively. The polygraphic equipment and MESAM 4 equipment were placed on the subjects by separate teams. Records of PSG and MESAM 4 were analyzed in double-blind fashion. With the MESAM 4 computerized analysis, three indices based on SaO_2 (ODI), on heart rate (HVI), and on snoring (ISI) were obtained, and the number of abnormal respiratory events occurring during the time selected for analysis (TAT) were determined. Polysomnographic records were scored by 30-s epochs following the American Sleep Disorders Association standards for sleep states and stages and for sleep-related events, including sleep apneas, hypopneas, and periodic leg movements. Following independent scoring, 26 subjects were identified

with OSAS by PSG, while MESAM 4 identified 25 subjects with OSAS using oxygen algorithm; all had a respiratory disturbance index ≥ 10 with PSG. Results of each polysomnogram and each MESAM 4 analysis were compared. With the polysomnogram used as a standard, the degree of error for each variable with the MESAM 4 was calculated. Specificity and sensitivity of the most accurate index of the MESAM 4, the ODI, were 97 percent and 92 percent, respectively. The other two indices, HVI and ISI, were less accurate: specificity and sensitivity were 32 percent and 58 percent for HVI and 27 percent and 96 percent for ISI. Nevertheless, a combination of all three indices (ODI, HVI, ISI) would have prevented the two false-positive cases we observed. The results of this validation study show that MESAM 4 can be helpful to general practitioners, clinicians, and epidemiologists as a low-cost screening device for subjects with OSAS and habitual snoring.

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ANS=autonomic nervous system; EDS=excessive daytime sleepiness; HVI=HR variation index; ISI=intermittent snoring index; ODI=oxygen desaturation index; PSG=polysomnography; RDI=respiratory disturbance index; TST=total sleep time

For several years, there has been interest among clinicians for a portable device that could be used at home to signal the presence of abnormal respiratory patterns during sleep. Such a device would be useful to physicians in many ways: it would enable them to perform regular follow-up of patients treated with nasal continuous positive airway pressure (CPAP) or other treatments, to follow at-risk populations (obese, COPD, etc) on a long-term basis, or to perform epidemiologic investigations on the prevalence of syndromes such as obstructive sleep apnea syndrome (OSAS). European clinicians and researchers in particular have emphasized the importance of such equipment. However, very few, if any, of the ambulatory or automatic systems currently advertised for use in sleep medicine have been appropriately validated.^{1,2}

We report herein the double-blind investigation of

one of these devices: the MESAM 4. This device is currently approved for sale in western Europe and the United States. We compared the results obtained with MESAM 4 and software version 3.1 with those tabulated from standard polysomnography.

METHODS

The Equipment

The MESAM 4 is a four-channel digital recording device that was developed by Madaus Medizin Elektronik. It is the second generation of the MESAM line, derived from the MESAM 2, a two-channel device that was initially developed through a joint effort of Madaus, Inc, and the University of Marburg (Germany) Department of Internal Medicine to monitor heart rate (HR) and snoring sounds.^{3,4} The MESAM 4 uses the previously tested HR and breathing sound hardware and software capabilities of the MESAM 2, but a pulse oximeter and a position sensor have been added. Briefly, the device is a small box (190 mm $\times$ 135 mm $\times$ 45 mm) with a total weight of 892 g, including 6 AA 1.5-V batteries and electronic circuit boards. The HR is monitored through a single-lead ECG (modified V_2), and R-R intervals are measured in milliseconds. Simultaneously, the time interval is compared with the value placed in the permanent memory. Snoring sounds are monitored through an electric subminiature microphone, type MCE

*From the Stanford University Sleep Research Center, Palo Alto, California.

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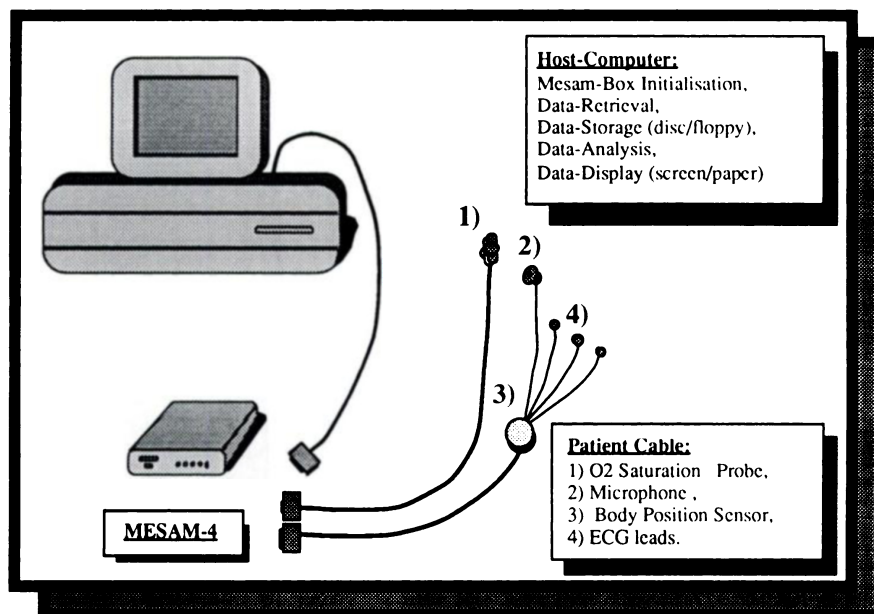


FIGURE 1. MESAM 4 is represented with the different leads used to monitor subjects. A MS-DOS® system personal computer is necessary to initialize the equipment for each subject and to retrieve the data. Data can be seen on the screen or printed as hard copy to keep in the patient's chart.

2,000 (frequency range, 30 to 20,000 cycles/s $\pm$ 2 dB, sensitivity 0.6 mV/microbar at 1,000 cycles/s $\pm$ 4 dB; available from Conrad Electronics, Hirschau, Germany). The microphone is encapsulated in such a way that it stands 2 mm from the skin to avoid the noise caused by rubbing, and it is taped above the larynx. The 2-mm small "pit" communicates through a 0.5-mm channel that allows air movements so as to avoid pressure changes related to neck movement on the membrane of the microphone (Fig 1).

Snoring sounds have been defined based on power spectrum analysis of sounds.^{3,4} If the relative power of the frequencies between 100 and 800 cycles exceeds 50 percent of the total power, "snoring" is identified and one bit is set in the MESAM device. Another bit takes total power of the sound into account. If the volume exceeds a predefined threshold corresponding to "loud snoring," which is defined by high microphone output (>1.1 mV at 1,000 cycles/s), another bit is set. Eight bits of information are collected every second, and they are stored in a solid state memory (64 kilobytes of RAM). Oxygen saturation is measured with a finger probe. The pulse oximeter used and packaged herein is commercially available separately through a different company. (We did not validate the pulse oximeter against blood gases drawn throughout the night, as it was not the goal of the study. However, a comparison between this pulse oximeter and another available one, the Biox Ohmeda [with finger probe] was initially performed on ten patients with obstructive sleep apnea, with the compared probes placed on the same finger of either hand. The two oximeters showed exactly the same number of oxygen saturation drops of 3 or more percent).

The body position sensor, a flat cylinder 18 mm high with a diameter of 50 mm, was placed on the lower part of the sternum of the subjects.

The beginning of the recording is programmable; thus, attachment of the device is independent of the start of the recording. A personal computer (IBM compatible) is used for data analysis. Software provided with the equipment is used for the automatic analysis of HR, breathing sounds, SaO₂ drops, and the printing of data as hard copy (Fig 2). The algorithms used for HR and snoring analyses are partially described in publications of the Marburg University research group^{3,5} but are not disclosed by the company at the

purchase of the equipment.

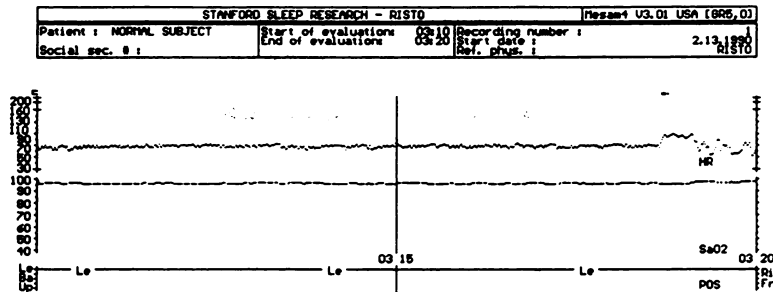
Previous publications concerning the MESAM 2 emphasized that results can be displayed on the computer screen or printed on paper at 10-min epochs for hard copy and that hand scoring can be performed. A similar hard copy with 10-min intervals can be obtained from MESAM 4 recordings. This function allows visual display of the monitored variables and hand scoring based on the simultaneous presence of a snoring-pause-snoring pattern associated with R-R interval variation (bradycardia) and of SaO₂ drops. MESAM 4 is sold with a proprietary analysis program that was tested in the study (version 3.1).

Study Design

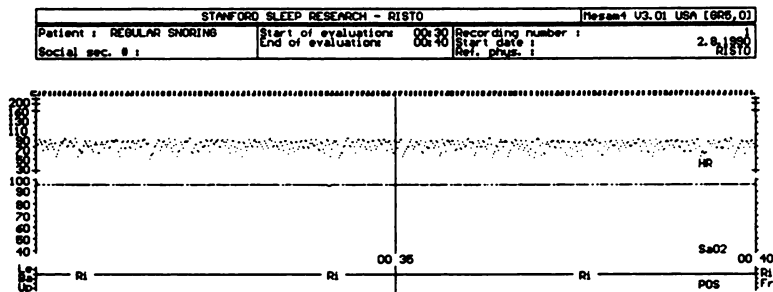
The studied population were patients seen at the sleep clinic for a sleep/wake-related complaint. Each subject had clinical interviews performed by physicians not involved in the study. Based on clinical impressions, patients were tentatively classified following the International Classification of Sleep Disorders (ICSD-90) nosology,⁶ and a decision to perform a polygraphic monitoring was made. Patients were assigned randomly by administrative personnel to one of five monitoring bedrooms. The MESAM 4 equipment was used systematically three nights per week on the subject in a given bedroom, and it was placed on subjects by research team members who were independent of the patient care team and were also not involved in MESAM analysis. Patients were asked to be in the monitoring facilities by 7 PM. They were fitted with the usual monitoring equipment and the MESAM 4 between 7 and 9 PM. According to their preference and personal routine, patients retired between 9:30 and 11:30 PM and were awakened between 6:30 and 7:30 AM the next morning. MESAM 4 equipment was then delivered for analysis to one individual blind to any clinical or polygraphic monitoring information. Polygraphic recording and MESAM 4 analyses were performed simultaneously by individuals who were not involved in the monitoring and who were located in different buildings.

Polysomnography

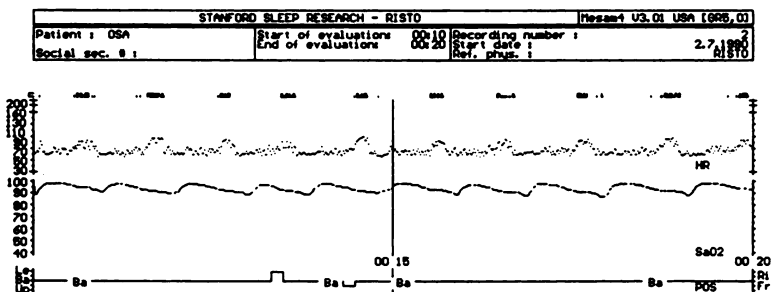
The following variables were systematically monitored: EEG (C3/



NORMAL SUBJECT



REGULAR, CONTINUOUS SNORING without APNEA



OBSTRUCTIVE SLEEP APNEA

FIGURE 2. Three examples of raw data in the 10-min epochs obtained with MESAM 4. All four recorded channels are displayed and labeled as HR (heart rate), SaO_2 (oxygen saturation), and POS (body position). The snoring tracing (top tracing) is always above the HR tracing (second tracing from the top). Snoring is indicated by black boxes. Height of the tracing varied with the loudness (calculated from spectrum analysis of sound) and with the length of the snore. The *upper panel* is a recording from a patient without sleep-related respiratory disturbance. No snoring sounds are present. The HR and oxygen saturation do not show significant changes. The body position is also stable, indicating the left side. At 3:19 AM, the subject is presenting an arousal from sleep (as confirmed by the simultaneous polysomnogram). At that time, a significant increase in HR can be seen in the MESAM tracing, accompanied by a short timed sound. The *middle panel* shows the MESAM recording of a subject with continuous regular snoring. Black dots in the snoring signals indicate noisy breathing interrupted by blank spaces that represent the expiratory part of the respiratory cycle. No changes in SaO_2 or body position occur. The HR shows enhanced sinus arrhythmia caused by the increased negative intrathoracic pressure swings. The *lower panel* shows a recording of a patient with severe OSA. The snoring signal shows clusters of black dots interrupted by blank spaces that represent the apneic interval. Snoring clusters indicate loud snoring and coincide with cyclical variations in HR. The SaO_2 tracing shows cyclical desaturations related to the apnea. The body position indicates that the subject is lying on his back.

A2-C4/A1); electro-oculogram; chin and leg electromyograms; and ECG (modified V_5 lead). Respiration was monitored (by uncalibrated Resptrace [thoracic and abdominal effort]). Airflow was monitored by nasal and oral thermistors. Oxygen saturation was monitored by a pulse oximeter (Biox Ohmeda). MESAM 4 was installed with the other sensors. Lights-out and lights-on times were indicated on the

MESAM information sheet.

Scoring

Polysomnography: The polysomnographic scoring team consisted of two trained technicians who scored sleep/wake, apneas, hypopneas and SaO_2 drops (3 percent or more), following the

ODI - RDI

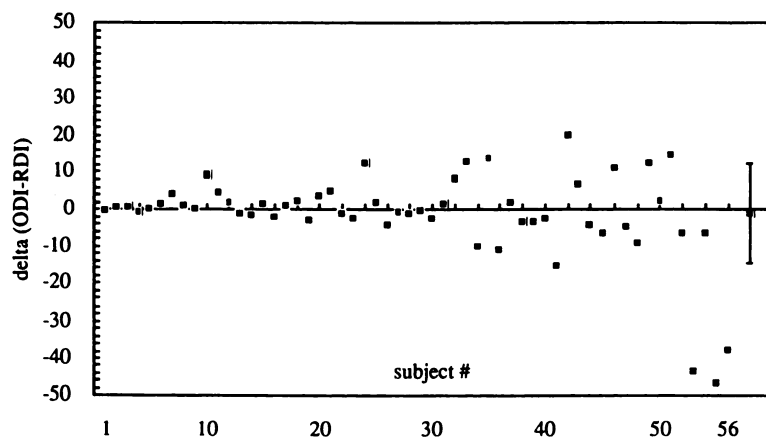


FIGURE 3. The delta (difference between RDI_{psg} and MESAM ODI) is presented in the figure. Each dot represents one subject, and each subject is identified by a number between 1 and 56. The farther away from the "zero" line the dot is located, the greater the discrepancy between polygraphically determined RDI and MESAM ODI.

international criteria for scoring sleep and respiration.^{7,8} Apneas and hypopneas were subdivided into central, obstructive, and mixed events. Sleep, respiration, and periodic leg movements were analyzed by 30-s epochs. These are the criteria accepted by the international community at this time.

MESAM 4: MESAM 4 was analyzed using the three proprietary computer-based scoring systems, *ie*, snoring-based, HR-based, and oxygen saturation-based. The printout of the different monitored variables was also obtained simultaneously, using the "full disclosure" mode, which presents data by 10-min epochs with the clock time at each epoch indicated. The lights-out and lights-on times were determined by the patient sleep logs, and the period to be analyzed was indicated to the computer. Patients also recorded in their logs any significant periods during the night in which they had been awake, and these periods were logged on the "full disclosure" printout and indicated to the computer as "wake periods." To confirm these logged "wake periods," the HR recording was used. Heart rate at the time of "lights-out" at the beginning of the night was determined. Normally in a subject without autonomic nervous system (ANS) lesions, a drop in HR occurs with sleep onset. Similarly, a return to faster HR is seen with awakening. Using the "lights-out" and "on" indications, the "wake" HR can be determined and a drop in HR associated with sleep onset can be noted. If a period is logged as "awake" during the course of the night by the monitored subject, patterns of HR decrease and increase similar to those noted at sleep onset and final awakening should also be seen in a subject without an ANS lesion. Since HR pattern changes can, thus, be used to confirm the logged time of "wake," they can help to time the "awakening" accurately. These periods of "wake" logged by a subject can also be indicated to the computer as "wake" and not included in the final analysis.

For this investigation, HR was taken into consideration only if patient logs indicated a "wake" period at a given time, and it was used only to confirm the patient write-up. No segment was eliminated from analysis if the HR pattern was of "wake" but the patient did not record the period in the log. The decision to run the study this way was made at the outset. We allow that a better "total sleep time" could have been calculated from the MESAM printout in some instances. Because in some instances a subject may not record wakefulness in his/her log book, or a subject may have some blunting of the ANS, or a technician may not conduct HR analysis, we decided to limit our information on "sleep" time to the period between lights-out and lights-on. This decision increased the risk of erroneous determination of "total sleep time" with MESAM 4.

Software

MESAM 4 calculates three different indices: (1) an oxygen desaturation index (ODI), which expresses the number of oxygen desaturations ≥ 3 percent per hour of analyzed time; (2) an HR variation index (HVI); and (3) a snoring index called the "intermittent snoring index (ISI)." These three indices are not integrated in a final score but are presented separately. Each of these indices gives an indication of the number of abnormal respiratory events (apnea/hypopnea) per hour of analysis time, which should resemble total sleep time, particularly if sleep log and HR recordings are considered on the "full disclosure" printout (Fig 2). Ideally, these indices should match the respiratory disturbance index (RDI) obtained with polysomnography.

RESULTS

The MESAM 4 is a safe, simple, easy-to-use device. Patient information can be entered when the MESAM 4 is prepared for monitoring. Preparation of the MESAM 4 before monitoring requires less than 5 min of the technician's time. Placement of the leads requires about 5 min. It may be performed by the subject, but in our study it was performed by a technical research staff member in the investigation. One recording was unusable due to displacement of the finger probe of the pulse oximeter.

Population

Fifty-six subjects were monitored. They included 46 men and 10 women whose median age was 47 ± 14 years. Patients were monitored for complaints of disrupted nocturnal sleep or excessive daytime sleepiness, and the suspected clinical diagnosis categories were narcolepsy, isolated daytime sleepiness (central nervous system hypersomnia), OSAS, or periodic leg movements during sleep. Clinical and polysomnographic data classified 26 patients as presenting with OSAS and 30 with "other sleep disorders."

Patients diagnosed as having OSAS had a median age of 47.5 ± 11.4 years, a median body mass index

(BMI) of $27.5 \pm 6.0 \text{ kg/m}^2$, and a mean RDI (ie, number of apneas and hypopneas per hour of sleep) of 41.3 ± 26.9 (range, 11 to 89). Patients with "other sleep disorders" (group B) had a median age of 46.5 ± 16.2 years, a median BMI of $26.5 \pm 4.0 \text{ kg/m}^2$, and a mean RDI of 3.2 ± 2.8 (range, 0.2 to 8.6).

Results Obtained with the MESAM 4

Analysis 1: The first analysis compared the overall population RDI with the three different indices calculated by MESAM software. The mean RDI was 20.9 ± 26.5 , the mean ODI was 19.5 ± 22.8 , the mean HVI was 16.5 ± 16.5 , and the mean ISI was 29.7 ± 17.8 . The correlation coefficients were 0.89 with ODI, 0.67 with HVI, and 0.54 with ISI.

As indicated above, our design determined "total sleep time" by the period between lights-out and lights-on. This increased the chance of an artificially high "total sleep time." If "total sleep time" values were erroneous, the indices calculated with these values would also be erroneous. Thus, we also performed an analysis of the number of events, which does not refer to total sleep time. The correlation coefficient improved only for the comparison between the number of oxygen desaturations ≥ 3 percent calculated by MESAM software and the number of apneas and hypopneas determined by scoring of the polysomnogram: $R = 0.92$.

Analysis 2: The next analysis considered the mean deviation of each of the three MESAM 4 indices and the total number of oxygen desaturation events from the polysomnographic findings. Deviations were equally likely to be above or below the polygraphic RDI, and the direction of the deviation was taken into consideration for each subject. In this part of the analysis we considered all 56 subjects as a total group, as opposed to analysis 3, in which we divided the group into two subgroups. The ODI had a mean deviation of -1.4 ± 12.0 , while HVI and ISI presented respectively a mean deviation of -4.4 ± 19.8 and $+8.8 \pm 22.6$ compared with RDI. We then considered the total number of respiratory events. Since MESAM 4 does not monitor the conventional variables that are used to determine total sleep time (TST), the length of the analysis period that we calculated for the MESAM 4 record (444.4 ± 92.8 minutes) differed from the TST (339.6 ± 92.9 min), which was determined from the nocturnal EEC, electro-oculogram, and chin electromyogram recordings.

This difference, of course, had an impact on the calculations of all indices: the RDI (abnormal respiratory events divided by *total sleep time*) will not be exactly the same as the ODI (abnormal respiratory events divided by *total analysis time*). From the above total sleep time/total analysis time data, MESAM 4 indices should indeed be smaller than RDI. To avoid

this systematic error, we considered the total number of abnormal respiratory events identified on the polysomnogram and the total number of oxygen desaturations on the MESAM 4. The results were different again, with a mean variation of $+26.6 \pm 59.7$ desaturations compared with the number of events scored as "sleep-related abnormal breathing events" by polysomnography (mean polysomnographic events = 101.9 ± 128.9). Heart rate and snoring indicators were also off by a mean of, respectively, $+4.8 \pm 120.8$ and $+113.3 \pm 132$. In summary, MESAM 4 overscored respiratory disturbances compared with polysomnography (PSG) on every considered variable.

Analysis 3: Rationale for the Analysis: MESAM 4 is proposed to general practitioners to identify individuals with a pathologic number of sleep apneas and hypopneas. Based on medical publications in the United States and Europe,^{9,12} an "abnormal amount" has been defined as ≥ 10 events per hour of sleep. We divided our population into two subgroups based on the RDI determined with polysomnography: one patient group had RDI values ≥ 10 (group A, 26 patients) and another had values < 10 (group B, 30 patients). We then performed the calculations presented in analyses 1 and 2 on each subgroup. Results for group A (RDI ≥ 10) were as follows: mean ODI had a mean deviation of -4.1 ± 16.9 , mean HVI had a mean deviation of -20.5 ± 15.8 , and mean ISI had a mean deviation of -0.3 ± 28.6 compared with mean RDI.

As in analysis 2, we decided to tally also the number of events, hopefully avoiding some of the discrepancies related to calculations of "total sleep-analysis time." The number of oxygen desaturation events > 3 percent SaO_2 was selected, as this parameter was the most reliable in analyses 1 and 2. A mean deviation of $+43 \pm 81.3$ events was observed, compared with the mean number of polysomnographic abnormal respiratory events.

Similar analyses were performed on patient group B ($n = 30$). Mean ODI deviation compared with RDI was -1.0 ± 3.5 and, when the total number of SaO_2 drops ≥ 3 percent was tabulated and compared with the number of polysomnographically determined abnormal respiratory events, the mean deviation was 12.5 ± 24.6 .

In summary, regardless of the patient group, there were differences in both types of measurements performed. If we consider MESAM 4-determined oxygen desaturation vs polysomnographically determined abnormal respiratory events, two types of errors may be questioned: (1) erroneous calculation of TST, as indicated above, and (2) SaO_2 drops related to movements during wakefulness or related to any artifact and counted as a "sleep-related" desaturation event by the MESAM 4. We thus checked two artifacts

that might impair ODI calculation: (1) complete slippage of the probe from the finger, and (2) artifactual SaO_2 drops due to abnormal finger pressure by the probe. MESAM 4 recognized these two conditions as artifacts. We also compared the lowest SaO_2 measured during the night for each subject with polysomnographic pulse-oximetric equipment vs MESAM 4 equipment. The mean deviation was $+2.7 \pm 8$ percent for group A and -1.6 ± 3.2 percent for group B.

Figure 3 presents the deviation ODI/RDI for each individual included in the study. It should be noted that the three subjects on the right side of the figure, who appear to be outliers due to their high deviations, were, however, recognized with significant apnea by the MESAM 4. These three subjects had RDIs of 83.5, 84.9, and 88.9 events per hour of sleep, respectively. MESAM 4 gave abnormal but lower values: 40, 38, and 51. Undoubtedly, sleep was very fragmented, and the "total sleep time" and "total analysis time" calculations were very different. Also, some events did not lead to SaO_2 drops ≥ 3 percent. Despite these errors, these subjects were scored with "significant apnea" and recognized with "abnormal breathing during sleep" by MESAM 4.

Analysis 4: Misclassification in Groups A and B by MESAM 4: Considering the above results, two of 26 OSAS subjects (subjects A and B) had an ODI ≤ 10 , as calculated by MESAM software, and one (subject C) of the 30 subjects with a normal RDI (RDI < 10) presented an ODI > 10 . Investigation of the two subjects misclassified with an ODI ≤ 10 (A and B) indicated the following: subject A had an RDI of 13 and an ODI of 3; subject B had an RDI of 15 and an ODI of 4. They presented, respectively, 28 and 22 events with the MESAM 4 algorithm and 103 and 110 with polysomnography. However, polysomnography revealed in both subjects mainly hypopneas with mild desaturations. The lowest O_2 values for both subjects were 89 percent and 91 percent, respectively. The other indices, HVI and ISI, were 28 and 10 for subject A and 8 and 44 for subject B. Subject C, with an RDI of 6, had an ODI of 18, an ISI of 26, and an HVI of 2.

Analysis 5: What are the specificity and the sensitivity of each MESAM 4 index, considering that the subject is placed in the category of ≥ 10 or < 10 abnormal respiratory events per hour of sleep? The specificity of ODI, the most accurate index, is 97 percent and sensitivity is 92 percent. The specificity of HVI is 32 percent and sensitivity is 58 percent. The specificity and sensitivity of ISI are 27 percent and 96 percent, respectively.

COMMENTS

There is growing concern in the European and American public health field about the diagnosis of OSAS patients. On one hand, if routine polysomno-

grams are not performed, a large portion of the OSAS population may not be recognized. On the other hand, polysomnography is an expensive and effort-intensive procedure. Undoubtedly, recognition by general practitioners of patients in need of further evaluation and referrals to specialized centers with cost-effective approaches will be helpful. Oriented questionnaires may also be helpful, although they only elicit subjective responses. Several studies performed in association with the multiple sleep latency test have indicated the poor quality of subjective appreciation of sleepiness (a major symptom of OSAS). This has led to a search for inexpensive devices that are able to provide a sufficient amount of information to the practitioner. To evaluate whether a new system can provide sufficient information with a small margin of error, the system is usually compared with another system that is well-known and accurate. The comparison between polysomnography and MESAM 4 was thus an obvious study design. It is true, however, that polysomnography has its limitations, as it is based on human scoring. However, in our own center, trained technologists have very high scoring agreement for sleep apnea (> 98 percent) and for hypopnea (97 percent). As MESAM 4 will be used at home, it would have been interesting to perform some home-based investigations. However, the first step was to establish in the laboratory that there was sufficient concordance of findings to give credence to any home investigations.

Does the MESAM 4 provide more than a simple nocturnal oximetry recording in the evaluation of subjects? Validations of nocturnal oximetry as a screening technique for OSAS have been attempted in individuals already suspected of having breathing disorders during sleep, but it must be emphasized that a systematic evaluation of subjects with a sleep-related complaint, particularly excessive daytime sleepiness (EDS), has not been performed. However, it is difficult to compare the above results with pure nocturnal oximetry studies because of the narrow patient selection that occurred before testing. If we consider results obtained on preselected populations (most commonly testing severe OSAS), reported sensitivity and specificity calculations of nocturnal oximetry have been variable and usually worse than those noted herein.^{13,14} MESAM 4 appears to be reasonably able to recognize SaO_2 drops and to automatically extract an index and a total number of events that have clinical relevance. As such, this equipment could undoubtedly help to screen subjects and give some indication of the degree of severity of the condition.

With the interpretation limited to reading of the summary sheet provided by the computer, the device demands very little of the physician's time. However, the device is best used when the different indices are considered in the "full disclosure," with the knowledge

that the HR and snoring indices have low specificity and sensitivity. These two indices may be used together with oxygen desaturation data to determine difficult cases. Interpretation of the "full disclosure" will initially require up to 15 min of the physician's time and a pattern-recognition training that may involve four to six recordings. The methods for "scoring" the HR and snoring patterns have already been well described by two different groups who investigated the MESAM 2;^{3,15} thus, they are not included in our report. However, it may help to have a "total analysis time" closer to the "total sleep time" and to point out hypopneas without SaO₂ drops but with intermittent snoring and cyclical variation of heart rate. MESAM 4 was evaluated herein using the lowest possible amount of physician participation and the highest involvement of automatic analysis. The ODI must always be coupled with evaluation of the total number of events, as TST will always be difficult to calculate without EEG recordings. We recommend that Madaus, Inc integrate their three indices and continue their programming efforts. Integration of all information may further improve sensitivity and specificity.

Finally, is this equipment sturdy enough to be used in patients' homes on a regular basis? Outside of the present study, we sent the MESAM 4 home for one night with 75 different patients who had no sleep disorders. Results: one microphone was broken, one patient took more than two weeks to bring the equipment back, and in four other subjects, the data were unusable due to disconnection of the equipment early during sleep. Data for these subjects were obtained the following night!

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