ORIGINAL ARTICLE

A Portal Recording System for the Assessment of Patients with Sleep Apnoea Syndrome

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Summary

The gold standard for the diagnosis and evaluation of sleep apnoea is overnight polysomnography. However, full polysomnography is an expensive and labour intensive procedure which requires the patient to sleep overnight in a hospital sleep laboratory. This paper describes the use of a commercial ambulatory microprocessor based system (Edentrace II) for the evaluation of fifteen patients aged 24 to 68 years with clinical features suggestive of sleep apnoea syndrome. With this portable recording system, sleep studies can be carried out unattended in a hospital ward and computer-assisted scoring of respiratory events can be performed.

Key Words: Assessment, Portable recording system, Sleep apnoea syndrome

Introduction

In patients with the sleep apnoea syndrome (SAS), repeated pauses of breathing during sleep lead to oxyhaemoglobin desaturation and fragmentation of sleep[1]. The clinical manifestations of the disorder include excessive daytime sleepiness, haemodynamic changes and cardiovascular and cerebrovascular problems[2].

The gold standard for the diagnosis and evaluation of sleep apnoea is overnight full polysomnography which involves continuous all-night recordings of electrophysiological variables consisting of electroencephalogram (EEG), electro-oculogram (EOG), chin electromyogram (EMG), nasal and oral airflow, thoracoabdominal respiratory movements, arterial oxygen saturation (SaO_2) and electrocardiogram (ECG)[1,3]. These recordings allow staging of sleep, detection of oxygen desaturation and cardiac arrhythmias, differentiation of obstructive, central and mixed apnoeas, and the computation of the apnoea-hypopnoea index (AHI) or respiratory disturbance index (RDI) which is a measure of the severity of sleep apnoea. However, full polysomnography is an expensive and highly labour intensive procedure which requires the patient to sleep overnight in a hospital sleep laboratory. There is a growing number of commercial portable computerised (and constantly upgraded) systems that utilise various combinations of pulse oximetry, oronasal airflow, thoracic and abdominal efforts, snoring sound, ECG and position sensors which reduce the cost of investigation and permit studies to be carried out unattended in a hospital ward or even in an ambulatory setting at home[4,5].

I describe below the use of one of these portable systems – the Edentrace II multi-channel recording system which has been validated against overnight polysomnography[6-9], for the assessment of fifteen patients with clinical features suggestive of SAS.

Materials and Methods

Subjects

Patients who were referred to the Chest Clinic and those who were admitted to the medical wards of the University Hospital, Kuala Lumpur in April to July 1995 with a history of excessive fatigue and excessive daytime sleepiness associated with chronic nocturnal heavy snoring with or without witnessed apnoeic episodes during sleep and nocturnal choking were

assessed by the author. Each patient also underwent an examination by the ear, nose and throat (ENT) surgeon to exclude any anatomical defect of the upper airway which might predispose the patient to develop obstructive sleep apnoea. Laboratory investigations included haemoglobin, haematocrit, thyroid function tests, respiratory function tests and awake supine arterial blood gases while the patient was breathing room air. The respiration of each of the patients during an overnight sleep in the general medical ward was assessed using the Edentrace II portable recording device. The placement of electrodes and sensors on each warded patient was performed by the author in the evening at around 1900 hr and the patient was instructed to switch on the recorder when he was ready to go to sleep. The night-duty nurse was instructed to make sure that the recorder was switched on at 2100 hr irrespective of whether the patient was already aslseep by then. The overnight recording was terminated at around 0730 hr the next morning.

Equipment

The Edentrace II system (EdenTec Corporation, Eden Prairie, MN 55344 USA) is a commercial multi-channel recording system that consists of a portable digital device for recording heart rate, thoracic cage respiratory effort, oronasal airflow, SaO_2, body position and snoring sounds. The recorder is a small box (187 mm x 286 mm x 89 mm) weighing 1.5 kg capable of recording up to 13 hours of physiological data with ECG.

The measurement of heart rate and the recording of respiratory chest wall movement by means of transthoracic impedance require the placement of two pregelled surface electrodes on either lateral side of the patient's chest along the mid-axillary line slightly below the level of the nipples. Thermistors in front of the nostrils and mouth detect airflow. The combined signal from the right and left nostrils and the mouth is recorded. Body position is measured by a gravity sensor. The patient belt is worn snuggly around the patient's upper abdomen.

The SaO_2 is measured with a Nellcor finger oximeter probe (SaO_2 accuracy: 70-100% ± 2 per cent points, 61-69% ± 3 per cent points, 0-60% unspecified). The unit is able to detect body movement by comparing electrical signals from the ECG and pulse oximetry recordings; a discrepancy between these signals is indicated as "motion" on the saturation channel.

Snoring sounds are monitored through an electric subminiature microphone (frequency range: 100-1000 Hz, low level detection: 90 ± 4 db at 500 Hz, high level detection: 96 ± 4 db at 500 Hz) which is taped in front of the thyroid cartilage.

As the Edentrace II system does not record EEG, EOG or chin EMG, wakefulness and the stages of sleep cannot be determined directly. Total sleep time had to be estimated by the use of a patient diary in conjunction with visual assessment of the overnight tracing for evidence of an awake state as suggested by movement (unassociated with respiratory events) or artifact (appearing on any of the channels) and acceleration of the heart rate.

With the Edentrace II Analysis and Archiving Software (EAS) that is provided, recorded data can be downloaded to an IBM compatible personal computer (386 DX 25 MHz, 40 Mb or larger hard drive, 4 MBytes available memory) for analysis. The EAS allows automatic analysis of heart rate, chest impedance, oronasal airflow, SaO_2 drops and snoring sounds, the scoring of apnoeas and hypopnoeas, and the printing of data as hard copy. The downloading of recorded data and automatic scoring of the recording takes less than 30 minutes. The results of analysis and waveforms of the recorded parameters can also be displayed on the computer screen for viewing or visual confirmation of the results of the computer-assisted analysis and for hand scoring.

Apnoeas and hypopnoeas are scored according to standard definitions based on respiratory, airflow and oximetric findings[1]. Apnoeas are classified as central, obstructive, or mixed. Obstructive apnoea is defined as cessation of oronasal airflow for at least 10 seconds despite continuing respiratory efforts. Central apnoea is cessation of oronasal airflow for at least 10 seconds with a corresponding absence of respiratory efforts. A mixed apnoea is a combination of an initial central component followed by an obstructive component. In practice, mixed apnoeas and obstructive apnoeas are considered to be the same. Hypopnoea is defined as a

drop in airflow of 50% or more below the average amplitude for at least 10 seconds with a 4% drop in SaO_2. Desaturation of at least 4% is considered clinically significant[10].

The AHI or RDI is the sum of apnoeas and hypopnoeas divided by the number of hours of sleep. An AHI of greater than 5 is considered abnormal[2].

Results

All the patients were males. Their anthropometric data and medical history are summarised in Table I. The majority of the patients had short thick necks and most of them were either overweight (body mass index of 25 kg m^{-2} or more) or obese (body mass index 30 kg m^{-2} or more). ENT examination revealed each of the patients to have a crowded oropharynx with an oedematous uvula due to chronic vibratory trauma associated with snoring. In addition, patients 1, 2, 5 and 11 had relatively large tongues. The investigation findings and the results of the overnight recordings with the Edentrace II system are summarised in Table II and Table III respectively. The room air arterial blood gases of 4 patients (patients number 3, 10, 12 and 13) showed significant hypoxaemia and hypercapnia while they were awake. However, all the patients did not have polycythaemia despite recurrent oxygen desaturations during sleep which in some patients were very severe and prolonged (Table III).

Examples of computer printout of full-disclosure data are shown in Figures 1a, 1b and 1c. Cyclical variations in heart rate, a feature of the sleep apnoea syndrome[11], are shown in Figure 1a manifesting as bradycardia during apnoea alternating with tachycardia on resumption of breathing (top tracing).

Table I
Anthropometric and clinical data of patients

Patient no.	Age (yrs)	BMI (kg m^{-2})	Duration of symptoms of SAS	Associated conditions
1	66	25.6	3 yrs	Hypertension, rhinitis
2	40	34.6	2 yrs	Hypertension
3	34	48.2	3 yrs	–
4	24	52	2 yrs	Rhinitis
5	35	26.9	2 yrs	Hypertension, rhinitis
6	42	24.8	5 yrs	Hypertension, rhinitis
7	51	26.5	2 yrs	Rhinitis
8	59	25.9	8 mths	Hypertension, ESRF
9	38	33.2	3 yrs	Hypertension, rhinitis
10	42	38.5	5 yrs	Rhinitis
11	41	35.8	2 yrs	–
12	29	45.2	2 yrs	–
13	43	34.0	9 yrs	Asthma
14	33	25.0	4 yrs	–
15	68	24.9	8 yrs	Hypertension, diabetes, ischaemic heart disease, rhinitis

BMI – body mass index = weight (kg)/height² (m^2)
SAS – sleep apnoea syndrome
ESRF – end-stage renal failure

Table II
Results of laboratory investigations

Patient no.	Haemoglobin (g l^{-1})	FEV1 (% predicted)	FEV1/FVC (%)	PaO_2 (kPa)	$PaCO_2$ (kPa)
1	146	72	85	11.6	NA
2	157	100	96	11.7	4.7
3	161	66	81	9.3	6.6
4	144	85	79	10.1	3.2
5	153	81	88	11.3	4.9
6	146	98	97	13.4	4.8
7	151	81	79	12.0	4.9
8	125	78	97	14.0	5.7
9	160	86	86	13.6	5.5
10	142	83	79	8.9	6.3
11	158	94	89	12.8	5.6
12	165	43	84	8.4	8.4
13	139	57	78	9.4	6.3
14	137	87	86	13.9	4.5
15	124	87	87	10.2	5.4

FEV1 – *forced expiratory volume in one second*
FVC – *forced vital capacity*
PaO_2 – *arterial oxygen tension*
$PaCO_2$ – *arterial carbon dioxide tension*
NA – *not available*

Similarly, the heart rate tracing in Figure 1c shows brady-tachyarrhythmias in association with the apnoea and hypopnoeas. The motion annotation parameter detects gross body movement as a result of arousal and awakening from sleep and is recorded as bold lines superimposed on the oxygen saturation waveform (Figures 1a and 1c). The snoring clusters in Figures 1a and 1c coincide with breathing. The event quick-check bars at the bottom allow data to be visualized at a glance. The length of the bar represents event duration.

Thyroid function tests did not reveal any of the patients to suffer from hypothyroidism, a condition that predisposes to the development of sleep apnoea[12].

Discussion

Recently recognized adverse consequences of untreated SAS such as cardiovascular, cerebrovascular and motor vehicle accidents[13-17] would mean expeditious diagnosis and treatment of the condition are necessary. However, laboratory-based full polysomnography for the assessment of SAS is costly and labour intensive and is of limited accessibility to most patients who may be suffering from the condition[18]. As the need for studies increases, portable systems offer a less costly but comparable efficacious alternative to laboratory-based studies[6-9]. Such portable systems allow recording to be carried out unattended and do not need personal vigilance of an technician or medical personnel during the patient's sleep[4,5].

Redline *et al*[9] compared recordings by standard polysomnography and portable recordings using Edentrace model 4700 and found that both the number of respiratory disturbances and the degree of oxygen desaturation detected on the polysomnogram correlated very well with the values obtained on portable recording.

High sensitivity is of importance for any method

Table III
Results of overnight recording with Edentrace II recorder

Patient no.	No. of hours slept*	Number of apnoeas			Number of hypopnoeas	RDI (per hour of sleep)	T_{90} (%)	T_{80} (%)	Lowest SaO_2 during sleep (%)
		C	O	M					
1	9.5	49	5	4	60	12.4	1.4	0	86
2	10	40	72	169	377	65.8	30.6	9.8	64
3	10.5	59	316	137	595	105.4	28	42.3	<60
4	12	154	138	87	453	69.3	16.9	46.3	<60
5	11	174	48	184	525	84.6	31.1	46.2	<60
6	6.5	47	61	32	299	67.5	8.2	5.7	<60
7	7	81	5	3	79	24	0.4	0	85
8	9	156	–	–	208	40.4	16.3	4.2	<60
9	7	301	47	19	408	110.7	15	<0.1	78
10	2.5#	45	36	38	102	88.4	23.8	45.8	<60
11	10	175	8	87	405	67.5	17.6	32.2	<60
12	9.5	7	76	20	547	68.4	29.3	50.5	<60
13	7.5	24	5	–	165	25.9	12.1	0.9	67
14	6	56	2	4	36	16.4	0.1	<0.1	76
15	8.5	66	57	74	355	64.9	2.8	0.2	75

* – *estimated from patient's sleep diary*
C – *central apnoea,* *O* – *obstructive apnoea,* *M* – *mixed apnoea*
RDI – *respiratory disturbance index*
SaO_2 – *oxygen saturation; values less than 60% are not accurate*
\# – *chest wall impedance electrodes and pulse oximeter connections fell off 2 1/2 hours after the start of recording*
T_{90} – *% of sleep time during which SaO_2 fell between 80 and 90%*
T_{80} – *% of sleep time during which SaO_2 fell below 80%*

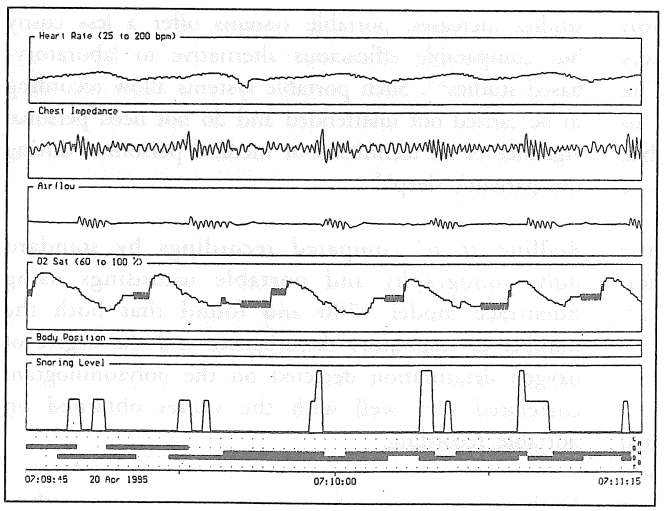

Fig 1a. Full-disclosure computer printer output waveforms of a representative 2 1/2-minute epoch from a study of a patient with severe obstructive sleep apnoea showing 6 episodes of obstructive apnoea with attendant cyclical oxygen desaturations related to the apnoeas.

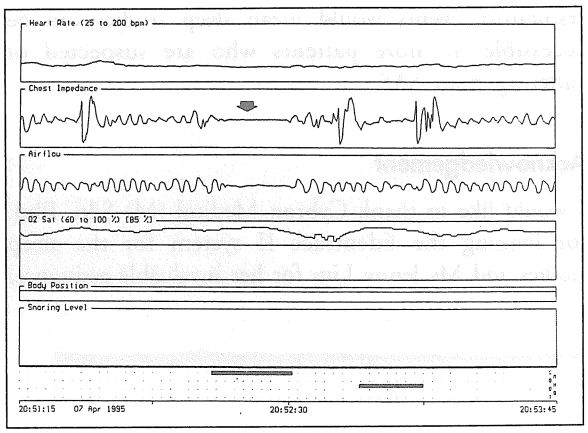

Fig 1b. Waveforms in a 2 1/2-minute epoch showing central sleep apnoea. The high frequency oscillations (arrow) on the chest impedance channel are cardiac artifacts and do not reflect breathing activity.

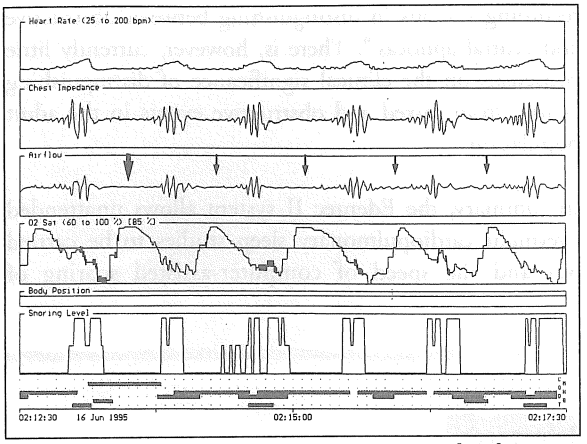

Fig 1c. Printout of a 5-minute epoch showing a mixed apnoea (broad arrow) with an initial central component followed by the obstructive component. The subsequent four disordered breathing events are hypopnoeas (thin arrows). The second and fourth hypopnoeas are more prolonged causing the corresponding oxygen saturation nadirs to fall below 60% and are therefore clipped off on the data display.

suggested for screening purposes. Studies have shown that when applied to a patient population with the presumed diagnosis of SAS, certain portable recording devices appear to be highly sensitive (with sensitivity ranging from 78% to 100%) and specific (with specificity ranging from 67% to 100%) in establishing the diagnosis of this sleep-related breathing disorder[19]. An accurate diagnosis of SAS appears to be best in those patients with severe SAS and poorest in those patients with only mild respiratory abnormalities. In patients with atypical results or any disparity between the recording result, symptoms, clinical findings and history, full polysomnographic assessment is required.

Since the Edentrace II system does not record sleep variables, the identification and quantification of sleep stages are not possible. The precise duration and quality of sleep and whether the patient actually went into REM sleep cannot be documented. Patients who complain of excessive daytime sleepiness but who do not demonstrate classical evidence of disordered breathing events on portable overnight recordings may be suffering from the "upper airway resistance syndrome"[20]. This disorder is characterised by repetitive transient arousals that results in sleep fragmentation and daytime sleepiness. The arousals are related to an abnormal increase in respiratory efforts in response to an increased upper airway resistance during sleep. Such patients should undergo full polysomnography to exclude this disorder.

As the Edentrace II system does not record parameters for the direct determination of sleep staging and scoring of sleep time, calculation of the AHI (or RDI) is a potential problem. The AHI may be underestimated if the subject is awake for a significant part of the study as the AHI determined using total recording time is lower than AHI determined using total sleep time which can only be accurately calculated from a standard polysomnogram.

Sensor disconnection as happened in the case of patient number 10 may be a problem with unattended studies. In addition, portable unattended recording devices are potentially subject to data loss or distortion because of equipment malfunction, tampering by the patient or power failure[19]. Apart from that, many articles on validation studies have commented on the inconsistent reliability and inaccuracy of portable

recording systems in distinguishing between obstructive and central apnoeas[19]. There is, however, currently little consensus on the clinical significance of distinguishing central from mixed and obstructive events in the adult population[9].

In summary, the Edentec II system allows unattended overnight cardiopulmonary sleep studies to be carried out and the speed of computer-assisted scoring of respiratory events would mean sleep studies can be accessible to more patients who are suspected of suffering from SAS.

Acknowledgement

I would like to thank Cybron Medical (M) Sdn. Bhd. for loaning the Edentrace II system for the sleep studies and Ms Jenny Lim for her invaluable assistance.

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