

Diagnostic Airway Pressure Recording in Sleep Apnea Syndrome

Magne Tvinnereim,

Philip Cole,

James SJ Haight, and

Victor Hoffstein

From the University Departments of Otolaryngology and Respiriology,

St Michael's Hospital,

Toronto, Canada

Correspondence and reprints:

Magne Tvinnereim MD

Haukeland University Hospital

Dept. of Otolaryngology/Head & Neck surgery

N-5021 Bergen

NORWAY

Phone: 47 - 55 29 80 60

Fax: 47 - 55 97 26 43

Tvinnereim M, Cole P, Haight J, Hoffstein V. *Diagnostic airway pressure recording in sleep apnea syndrome.* Acta Otolaryngol (Stockh) 1995; 115: xx - xx.

A comparison was made between polysomnographic recordings and recordings of airflow pressures in the pharynx and respiratory pressures in the esophagus of 10 adult sleeping subjects with differing degrees of apnea. Pressure measurements were obtained by microsensors mounted on a 7F gauge flexible catheter which sited them in the epi, meso and hypopharynx and the esophagus. Digitized overnight pressure data were stored on a PC memory card and subsequently displayed for analysis by means of a notebook computer. In two patients examination of 200 obstructive, mixed and central apneic events showed no significant differences in recordings of their incidence, duration or classification between polysomnographic and either paryngeal or esophageal pressure techniques. Onset of apnea was demonstrated with particular clarity by computer integration of the pressure tracings. The multiple pressure sensor method offered a further important advantage in detecting the caudal limits of pharyngeal obstructions by steep elevation of pressure gradient in the pharyngeal segment between adjacent sensors in which the caudal limit of the obstruction was sited. The multiple pressure sensor technique provided reliable and comprehensive diagnostic information of breathing disorders in sleeping subjects and together with its miniaturized recording equipment the method commends itself as suitable for home monitoring. **Key words:** site of obstruction, multiple pressure recordings, polysomnography.

INTRODUCTION

Breathing disorders in sleep can be diagnosed and their severity assessed by several different methods. Polysomnographic recording is widely used and whole night recording is preferable to shorter term testing.

If a diagnosis of idiopathic obstructive apnea syndrome is verified by objective tests, surgery and CPAP are methods of management commonly considered. CPAP provides control of the disease and improves prognosis regardless of the site of pharyngeal obstruction in patients who tolerate its regular use. UPPP is a frequent surgical alternative but success is unlikely unless the primary site of obstruction is localized to the palatopharynx. Determination of the site of obstruction is, therefore, a desirable diagnostic objective and various techniques including fiberoptic endoscopy (1) and imaging (2,3) have been employed but, although effective, they are impractical for routine over-night studies. As an alternative, continuous pressure recording in the esophagus and at different pharyngeal sites simultaneously (4-8), offers the possibility of detecting both obstructive breathing events and their obstructive site. The method can provide a practical adjunct to polysomnography, or even a substitute for it, with the additional advantage that miniaturization of recording equipment could enable it to be used by patients in the familiar environment of their home.

Pharyngeal airway pressure recording has been undertaken by means of open catheters and by single (5) and by multiple (6-8) pressure sensors mounted on a catheter. Each technique has clearly demonstrated both the increases in transpharyngeal differential pressures that accompany snoring and obstructive incidents and the caudal limit of obstruction.

The multiple pressure sensor recording system we have employed demonstrates the caudal limit of pharyngeal obstruction in apneic patients by a distinctive steep change in transpharyngeal pressure gradient between 2 adjacent sensors. The aim of the investigation described in this paper is to compare, second by second, the character, temporal incidence and duration of obstructive events as demonstrated by subocclusal pressure recordings with both esophageal pressure recordings and polysomnography.

MATERIAL AND METHODS

Ten patients (1F, 9M) aged 22 to 68 years were admitted to the Sleep Clinic, St Michael's Hospital, Toronto, for investigation of obstructive sleep apnea syndrome. Routine nocturnal polysomnography included measurements of EEG, EOG, chin and anterior tibial EMG, ECG, oxygen saturation using finger oximeter, oronasal flow using oral and nasal thermistors, snoring using a microphone-sound meter system as previously described (9), and movements of the chest wall and abdomen using inductance plethysmograph. Body position was monitored using infrared video camera. In addition, continuous pressure recordings were obtained from the epi, meso and hypopharynx and from the esophagus by means of microsensors (Reditech, Copenhagen, Denmark) incorporated in the wall of a 7 F gauge flexible plastic catheter. The microsensors were located (i) at the distal end of the catheter, (ii) at 150 mm and (iii and iv) at 35 mm's intervals proximally. The catheter was passed pernasally and positioned by placement of a visible marker just caudal to the rim of the soft palate and anchored firmly by adhesive tape to the upper lip. Positioning was confirmed by fiberoptic endoscopy.

A/D conversion enabled pressure data sampling from each transducer at 5 Hz to be logged for 8 h and stored on a PC memory card (2 Mb, OmniTech, Bergen, Norway). Subsequent scoring of the stored data from the PC card was performed with the aid of an IBM compatible notebook computer and marked pressure sequences were compared with synchronously marked polysomnographic recordings.

The transducers were calibrated and inserted about an hour before recording and they were tolerated in situ without discomfort for the duration of the experimental period of several hours.

The multiple micro-pressure-sensor transducer catheter and data-logger is shown in Fig.1, while localization of the sensors in the pharynx is demonstrated in a schematic drawing in Fig.2.

In each patient we determined the site of obstruction during apneas and classified them as high (H-between the two upper sensors), middle (M-between the second and the third sensor), and low (L-lower than the third sensor).

Analysis of variance was used to compare the number of obstructive apneas as determined by three groups of measurements: polysomnography, intrathoracic pressures and pharyngeal pressure. Similar analysis

apneas as determined by polysomnography and intrathoracic pressure measurements. All statistical analysis was carried out using SAS software, version 6.04 (The SAS Institute, Gary, NC).

RESULTS

The patient group consisted of 9 men and 1 woman who ranged in age from 20 to 68 years (mean \pm SD: 50 ± 13.0) and body mass indices from 20 to 52 kg/m² (mean \pm SD: 32.5 ± 10.1) (Table I).

Central apneas produced no pressure fluctuations and all tracings from the pharynx and the esophagus remained flat (Fig. 3a). By contrast, obstructive apneas were characterized by large and mainly negative pressure swings in the thorax and in the pharynx caudal to the obstruction (Fig. 3b).

Although the termination of an obstructive apnea is clearly demonstrated by an abrupt pressure change at the opening of the pharynx its precise onset is not readily differentiated from heavy breathing or snoring by scanning the raw pressure recordings. In order to demonstrate the onset more clearly the raw pressure signals were filtered, summated and integrated thus producing a characteristic enveloping curve in which the complete duration of the apnea could be accurately measured (Fig. 3b).

Raw and enveloped pressure curves from a sensor situated in the middle third of the esophagus are shown in Fig. 4. The principal differences between normal breathing, obstructive pharyngeal apneas and central apneas are shown. Regular, evenly distributed curves of fairly constant amplitude are produced by normal quiet breathing. During apneas associated with obstruction characteristic pressure changes are found in both raw and enveloped pressure curves. Similar changes are found when recordings are obtained from each of 3 more caudal sensors while the cranial sensor shows no pressure fluctuations during apneic events (Fig. 5a. Upper). Thus the segment between the 2 most cranial sensors demonstrates the greatest pressure gradient, indicating the site of obstruction in the upper pharynx. The patient with a more caudal site of pharyngeal obstruction demonstrates the greatest pressure gradient between the 2 most caudal pharyngeal sensors (Fig. 5a. Lower) which straddled the obstructive segment. During central apneas, on the other hand, no pressure swings are present in any of the tracings (Fig. 5b).

Subtracted curves (from subtraction of values between adjacent curves) clearly indicate differences in magnitude between pressure recordings from different levels that can be seen also in both raw and enveloped tracings. The segment immediately caudal to the obstruction characteristically demonstrates the greater pressures in the raw tracings, while the enveloped curves give a particularly clear view of differences in magnitude.

Comparison between the numbers of obstructive and mixed apneas, obtained by polysomnographic recordings and simultaneous subocclusal and esophageal pressure tracings, are shown in Table II. Agreement between the 3 series of recordings of both types of apnea showed no significant differences between groups. The pressure sensors are able to detect the short (5-6 s) obstructive portions of mixed apneas.

The sites of obstruction among the sleep apneic patients ($AI > 10$) in the series examined were predominantly in the upper pharynx (4/1).

Table III shows durations of obstructive apneas determined by polysomnography and pressure recordings in the esophagus as well as by the sensor in the pharyngeal segment immediately caudal to the obstruction. Mean values for duration are virtually identical and no significant differences were found between groups (Table III).

DISCUSSION

Recent studies (10) have shown micro-pressure-transducers to be as reliable in measuring intrathoracic pressures as the esophageal balloon technique. Furthermore, correspondence between recordings by polysomnography and a pressure sensor in the esophagus has shown the latter to be a good indicator of apneas (11). In addition, the caudal limit of apneic obstruction that has been determined by the serial positioning of a single pressure sensor in the pharynx (5) is demonstrated more reliably by records obtained from multiple sensors each located at a different site in the pharynx (6-8). The latter method reveals the caudal limit of a partial or complete obstruction by a recognizeably steep pressure gradient in the segment between adjacent pharyngeal sensors. Variation of the site of obstruction from time to time that was found in individual patients

f a night's sleep that was demonstrated by multiple pressure recording would not be detected by the catheter.

This investigation was undertaken to determine more rigorously than hitherto the precise incidence and classification of disordered breathing events as registered by digitized pressure recordings at the pharyngeal sites and to compare them with simultaneous esophageal pressure recordings and polysomnographic recording.

Analysis of 200 disordered breathing events recorded synchronously by polysomnography and the catheter sensor method confirms the latter as reliable and accurate in clearly demonstrating the incidence, duration and classification of disordered breathing events in sleeping subjects.

Upper obstructive pharyngeal recordings gave identical results (Table III) and these results differed distinctly from those obtained by polysomnography. In other words, the distinctively steep pressure gradient (in the caudal limit of obstruction) in a pharyngeal segment corresponded in incidence and classification of obstructive events demonstrated by synchronous polysomnography.

Upper obstructive and mixed apneas and hypopneas were readily detected and differentiated and their incidence could be assessed as accurately from integrated pressure recordings as by polysomnography.

Indeed, the onset of apnea, although often insidious, is demonstrated clearly by enveloped pressure curves (i.e. filtered and integrated curves, see Fig. 3).

Light stages of sleep could not be detected by pressure measurements but observation by a bed microphone recording of snoring might suffice. Furthermore, if a single night recording is unsatisfactory a repeat recording is a major upset.

In the 10 subjects who were investigated, a previous diagnosis of idiopathic obstructive sleep apnea had been made in 6 and apneic obstructions were demonstrated in 9. Of the 6 OSAS patients, the obstructions were predominantly in the upper pharynx in 5 and in the hypopharynx in the remaining one. We have also found a preponderance of upper pharyngeal obstructions in patients suffering from obstructive apneas. The number of our subjects is too small to draw firm conclusions about the site of obstruction but it is important to note that variation of site occurs. This variation may account

during the course of a night's sleep that was demonstrated by multiple pressure recording would not be detected so readily by a single catheter.

The present investigation was undertaken to determine more rigorously than hitherto the precise incidence, duration and classification of disordered breathing events as registered by digitized pressure recording at multiple pharyngeal sites and to compare them with simultaneous esophageal pressure recordings and with polysomnographic recording.

Comparison of 200 disordered breathing events recorded synchronously by polysomnography and the multiple pressure sensor method confirms the latter as reliable and accurate in clearly demonstrating corresponding incidence, duration and classification of disordered breathing events in sleeping subjects. Esophageal and subobstructive pharyngeal recordings gave identical results (Table III) and these results did not differ significantly from those obtained by polysomnography. In other words, the distinctively steep pressure gradient (in the caudal limit of obstruction) in a pharyngeal segment corresponded in incidence and duration with the obstructive events demonstrated by synchronous polysomnography.

Central, obstructive and mixed apneas and hypopneas were readily detected and differentiated and the duration of incidents could be assessed as accurately from integrated pressure recordings as by polysomnography. Indeed, the onset of apnea, although often insidious, is demonstrated clearly by enveloped pressure curves (i.e. filtered and integrated curves, see Fig. 3).

Onset and stage of sleep could not be detected by pressure measurements but observation by a bed partner or tape recording of snoring might suffice. Furthermore, if a single night recording is unsatisfactory repetition is not a major upset.

Of the 10 subjects who were investigated, a previous diagnosis of ideopathic obstructive sleep apnea syndrome had been made in 6 and apneic obstructions were demonstrated in 9. Of the 6 OSAS patients, the obstructive sites were predominantly in the upper pharynx in 5 and in the hypopharynx in the remaining one. Other investigators also have found a preponderance of upper pharyngeal obstructions in patients suffering from ideopathic obstructive apneas. The number of our subjects is too small to draw firm conclusions about typical sites of obstruction but it is important to note that variation of site occurs. This variation may account

for the unpredictability of UPPP. Thus overnight rather than short duration recording would be advantageous in determining a predominant site.

The example of the patient with hypopharyngeal (or possibly laryngeal) obstructions emphasizes the importance of an esophageal pressure sensor to ensure detection of unusually caudal obstructions. We found it impractical to place a pharyngeal sensor more caudally than mid-epiglottic level since it tended to enter the post cricoid region or the upper esophagus on swallowing and firm anchoring at the nostril was essential. Slight tension of the catheter that resulted from swallowing and anchoring maintained position of the sensors.

CONCLUSION

Our results indicate that over-night pressure recording in the pharynx and esophagus with a multisensor catheter can supply reliable and comprehensive diagnostic information on breathing disorders in sleep including the site of obstruction. For numbers, types and durations of the disordered breathing events, close to identity were shown between simultaneous polysomnography, subocclusal and esophageal pressure recordings. The subocclusal obstructive events documented by micro-pressure-transducer recordings, were shown to have exactly the same incidence and localisation (i.e. represent the same apneic event) as those demonstrated by polysomnography.

REFERENCES

1. Onal E, Lopata M. Periodic breathing and the pathogenesis of obstructive sleep apnea. *Am Rev Respir Dis* 1982; 126:676-80.
2. Rojewski TE, Schuller DE, Clark RW, Schmidt HS, Potts RE. Synchronous video recording of the pharyngeal airway and polysomnograph in patients with obstructive sleep apnea. *Laryngoscope* 1982; 92:246-50.
3. Haponic EF, Smith PI, Bohlman ME et al. Computerized tomography in obstructive sleep apnea. *Am Rev Respir Dis* 1983; 127:221-6.
4. Hudgel DW. Variable site of airway narrowing among obstructive sleep apnea patients. *J Appl Physiol* 1986; 61:1403-9.
5. Chaban R, Cole P, Hoffstein V. Site of upper airway obstruction in patients with idiopathic obstructive sleep apnea. *Laryngoscope* 1988; 98:641-7.
6. Tvinnereim M, Miljeteig H. Pressure recordings a method for detecting site of upper airway obstruction in obstructive sleep apnea syndrome. *Acta Otolaryngol (Stockh)* 1992; Suppl,492:132-40.
7. Woodson BT, Wooten MR. A multisensor solid-state pressure manometer to identify the level of collapse in obstructive sleep apnea. *Otolaryngol Head Neck Surg* 1992; 107:651-6.
8. Skatvedt O. Continuous pressure measurements in the pharynx and esophagus during sleep in patients with obstructive sleep apnea syndrome. *Laryngoscope* 1992; 102:1275-80.
9. Hoffstein V, Mateika JH, Mateika S. Snoring and sleep architecture. *Am Rev Respir Dis* 1991; 143:92-6.
10. Panizza JA, Finucane KE. Comparison of balloon and transducer catheters for estimating lung elasticity. *J Appl Physiol* 1992; 72:231-235.
11. Tvinnereim M, Mateika S, Cole P, Haight J, Hoffstein V. Intrathoracic pressure recordings in the diagnosis of obstructive sleep apnea: Portable transducer catheter vs. polysomnography. Unpublished data.

Address for correspondence:

Magne Tvinnereim MD

Haukeland University Hospital

Dept. of Otolaryngology/Head & Neck surgery

N-5021 Bergen

NORWAY

Phone: 47 - 55 29 80 60

Fax: 47 - 55 97 26 43

Legends:

Fig. 1. Photograph of catheter and logger.

Fig. 2. Schematic drawing of the micro pressure transducer catheter and location of sensors in the pharynx.

Fig. 3. Principal representation of: (a) Central apneas, (b) Obstructive apneas and calculation of enveloped curves.

Fig. 4. Raw and enveloped pressure curves from intraesophageal micro-pressure-transducer.

(a) unobstructed breathing, (b) central apnea, (c) obstructive apnea.

Fig. 5. Raw and enveloped (Filtered & Integrated) pressure tracings from sensors at 3 different pharyngeal levels and esophagus, demonstrating (a) obstructive apneas with upper and lower sites of obstruction, and (b) central apneas.

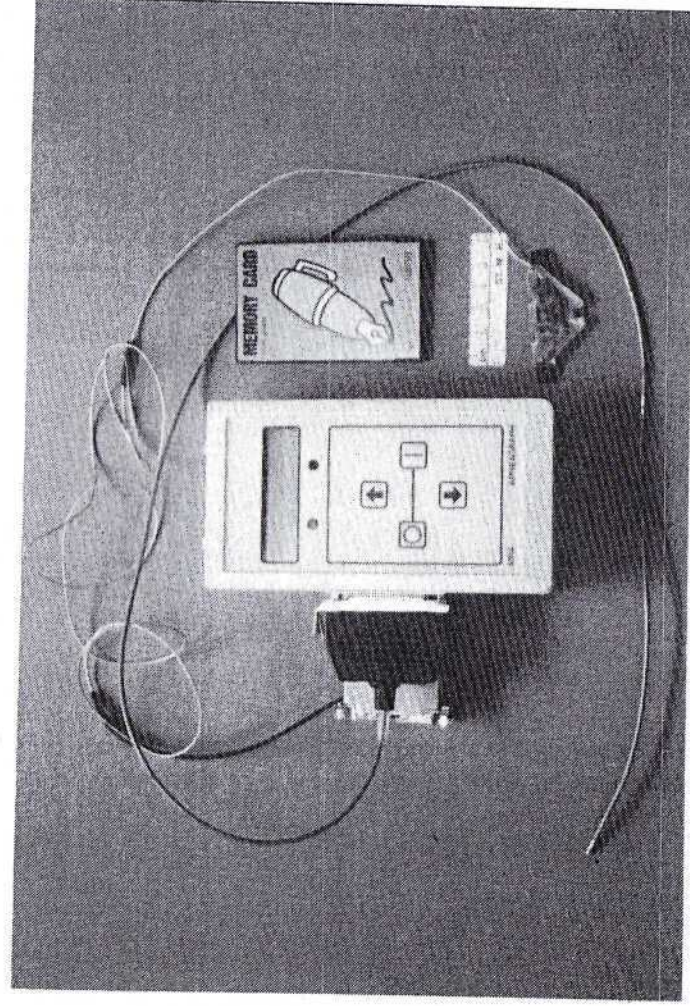


Fig.1

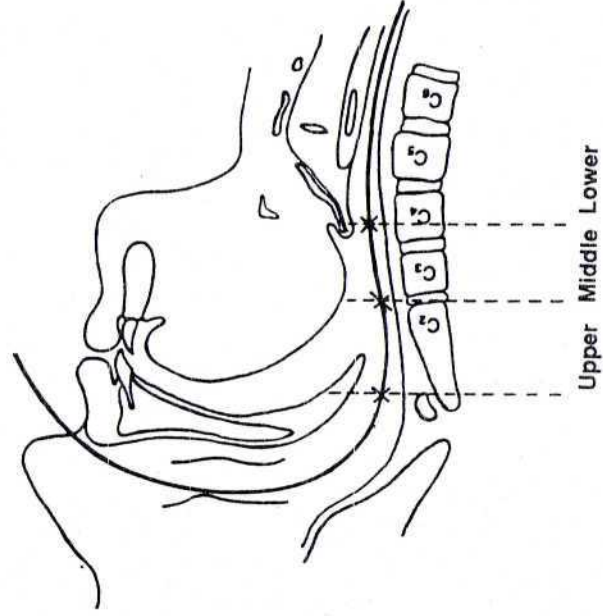


Fig.2

a) Central Apnea



b) Obstructive Apnea

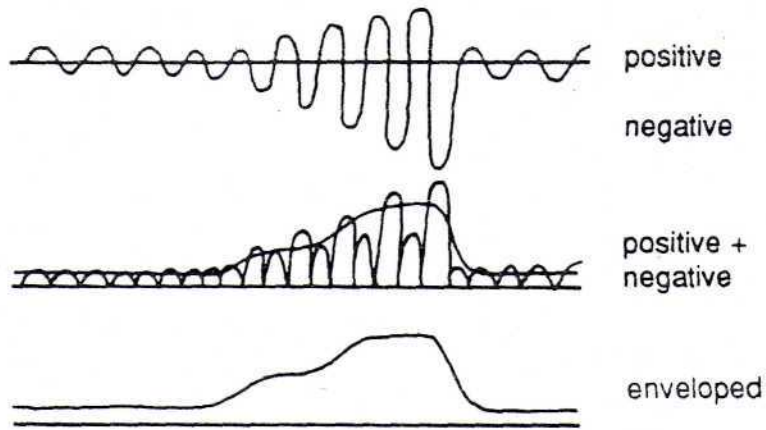


Fig.3

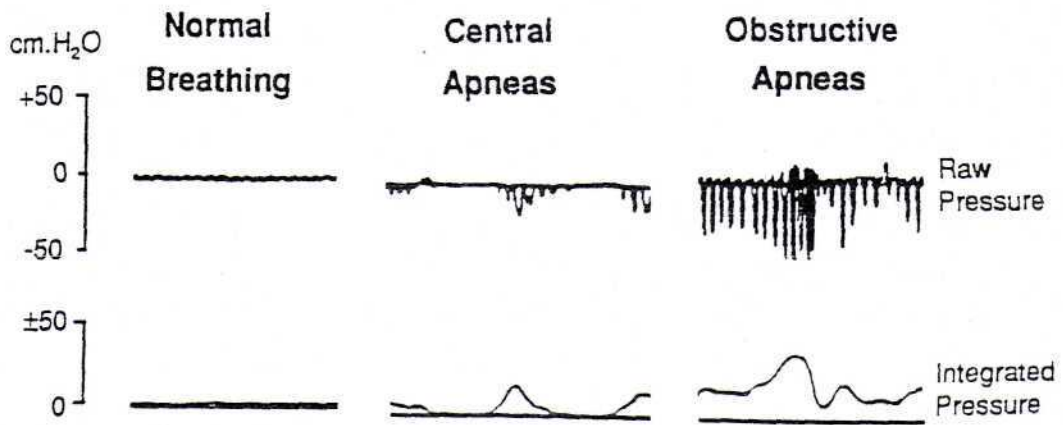


Fig.4

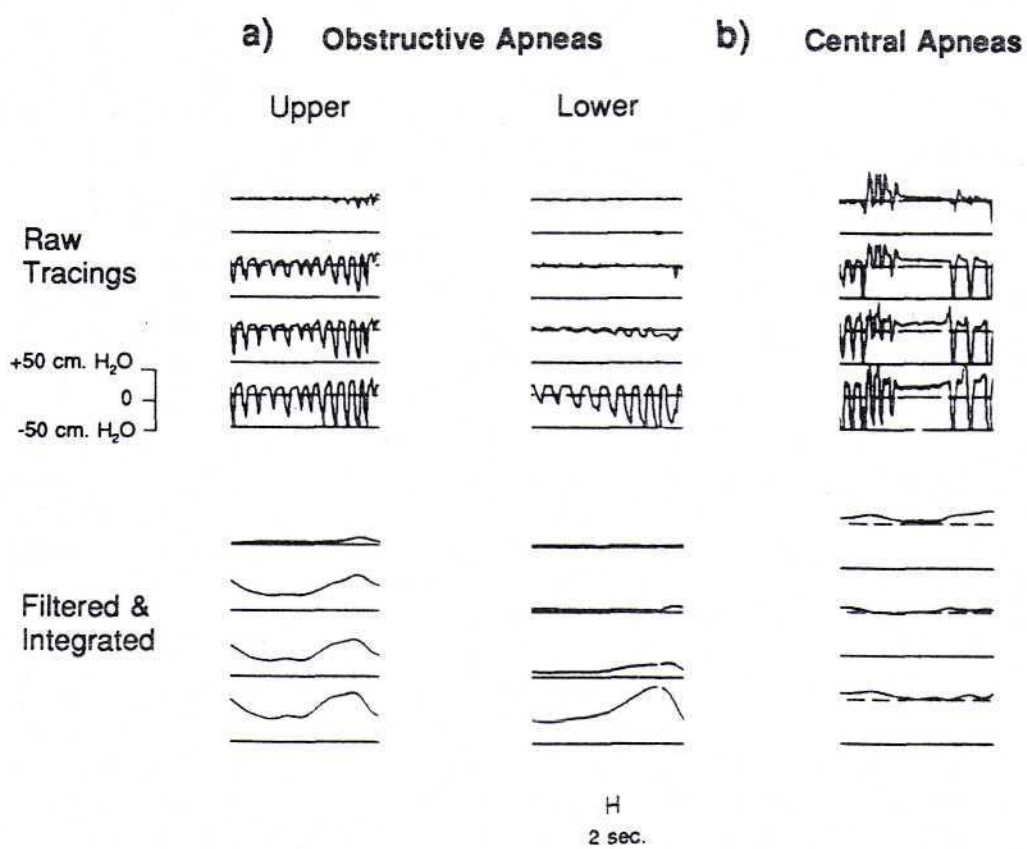


Fig.5

TABLE I. Anthropometric data.

Patient	Sex	Age	Height	Weight	BMI	Race
1	M	54	179	94	29,4	Caucasian
2	M	46	183	102	30,4	Caucasian
3	M	57	176	83	26,8	Caucasian
4	M	43	180	86	26,5	Caucasian
5	M	24	175	79	25,8	Caucasian
6	M	36	175	111	36,2	Caucasian
7	F	68	163	54	20,3	Caucasian
8	M	46	171	140	47,8	Caucasian
9	M	59	175	150	52,2	Caucasian
10	M	63	173	88	29,4	Negroid
Mean		49,6	175,0	98,7	32,5	
SD		13,3	5,5	28,7	10,1	

TABLE II

Numbers of obstructive and mixed apneas obtained by polysomnography (P) and by intrathoracic(I) and sub-occlusal(S) pressure recordings per hour of sleep (AI). Level of obstruction is determined from pressure recordings, as high(H), middle(M) or low(L).

PATIENT	OBSTRUCTIVE			MIXED			LEVEL OF OBSTR.		
	P	I	S	P	I	S	H	M	L
1	33	32	33	15	15	15	45	3	0
2	2	2	2	1	2	2	4	0	0
3	12	11	12	2	3	3	15	0	0
4	31	31	31	2	3	3	0	0	34
5	18	20	18	6	7	7	25	0	0
6	4	4	4	0	0	0	4	0	0
7	0	0	0	0	0	0	0	0	0
8	1	4	1	0	0	0	1	0	0
9	3	4	3	3	2	2	5	0	0
10	18	19	18	34	33	33	45	2	4
Mean	12	13	12	6	6	6	14	0,5	4
SD	12	12	12	11	7	7	18		

TABLE III

Duration of obstructive apneas (in secs \pm SD) recorded by polysomnography and by intrathoracic (IT) and sub-occlusal (SO) pressure sensors.

Patient	No. of apneas	Polysomnography	IT pressures	SO pressures
A	100	15.6 \pm 4.0	15.8 \pm 4.1	15.9 \pm 4.2
B	100	20.3 \pm 5.9	20.4 \pm 6.0	20.6 \pm 6.1