Rhinology, 40, 203-210, 2002

Flextube reflectometry and pressure-recordings for level diagnosis in obstructive sleep apnoea*

C. E. Faber[1], L. Grymer[1], O. Hilberg[2], O. Norregaard[3]

[1] Department of Otorhinolaryngology, University Hospital, Aarhus, DK-8000, Aarhus C, Denmark
[2] Department of Pulmonary Medicine, University Hospital, Aarhus, DK-8000, Aarhus C, Denmark
[3] Respirationscenter Vest, University Hospital, Aarhus, DK-8000, Aarhus C, Denmark

SUMMARY

The objective of this study was to compare sound reflections in a flexible tube (flextube reflectometry) with pressure-catheter recordings (ApneaGraph®) for identifying the predominant obstructive level of the upper airway during sleep.
Seventeen males with suspected obstructive sleep apnoea syndrome (OSAS) were included in the study.
The mean (standard deviation = SD) number of flextube narrowings per hour recording was 50.2 (20.4) and the mean (SD) RDI (respiratory disturbance index = apnoeas and hypopnoeas per hour recording) determined by the ApneaGraph® was 45.7 (20.2). The mean difference (SD) between the number of flextube narrowings per hour recording and the RDIs determined by the ApneaGraph® was not statistically significantly different from 0.
There was no statistically significant correlation between the percentage of retropalatal narrowing of the total narrowing (retropalatal and retrolingual narrowing) measured by flextube reflectometry and the percentage of retropalatal ("upper") obstructive apnoeas and hypopnoeas of the total number ("upper", "intermediate" and "lower") measured by ApneaGraph® (Spearman´s correlation coefficient r = 0.24, p = 0.36, N = 17).
In conclusion diverging results were found in flextube reflectometry studies and pressure-recordings performed on different nights regarding the level distribution of obstructions during sleep. Possible explanations of this discrepancy are discussed.

Key words: obstructive sleep apnoea, acoustics, airway pressure, diagnosis, upper airway

INTRODUCTION

Surgical procedures are sometimes performed to increase the pharyngeal volume to prevent upper airway collapse during sleep in patients with obstructive sleep apnoea syndrome (OSAS) (Fujita et al. 1981). However, the results of surgical treatment are not convincing (Bridgman and Dunn, 2000). Patients with mainly retropalatal obstructions respond better to uvulopalatopharyngoplasty (UPPP) than patients with mainly retrolingual obstructions. Consequently information regarding the predominant level of upper airway narrowing is required (Sher et al. 1996). Polysomnography (PSG) is the gold standard for providing information regarding the severity of OSAS but the level of obstructions is not identified.

The aim of this study was to compare results from flextube reflectometry with results from overnight continuous pressure measurements for identification of the level of obstructive predominance in OSAS. We chose to compare the flextube method with the pressure catheter method because pressure catheters have been used for a number of years and their reproducibility has been found to be relatively good (Rollheim et al. 1999). The agreement between pressure catheters and PSG for scoring respiratory events during sleep has also been demonstrated to be good (Tvinnereim et al. 1995).

The change in the RDI (respiratory disturbance index = number of apnoeas and hypopnoeas per hour recording) caused by the insertion of a flextube and a pressure catheter was also assessed.

List of Abbreviations: OSAS = Obstructive sleep apnoea syndrome; RDI = Respiratory disturbance index = apnoeas and hypopnoeas per hour recording; UPPP = Uvulopalatopharyngoplasty; PSG = Polysomnography; EEG = Electroencephalography; REM = Rapid eye movement; Sao2 = Arterial blood oxygen saturation; BMI = Body mass index (= weight in kilograms/(height in meters)2); CI = Confidence interval; SD = Standard deviation; Total MCA = minimum cross-sectional area of the nasal cavity (sum of right and left sides) measured by acoustic rhinometry.

* Received for publication: April 19, 2002; accepted: June 14, 2002

MATERIALS AND METHODS

Subjects

Twenty-two male patients referred to the Department of Otorhinolaryngology, Aarhus University Hospital, Denmark, for OSAS and/or snoring accepted to participate in the study. One person was excluded due to technical problems with the microphone of the flextube device. Four patients were excluded from the study because the pressure catheter device registered less than a total of 20 obstructive events. Consequently 17 patients were included in the study. Table 1 shows the characteristics of the subjects included in the study.

Table 1. Subject characteristics (n = 17).

	Mean	SD
Age (years)	49.4	9.4
BMI (kgm^2)	29.7	3.3
Neck circumference[1]	44.5	2.6
Epworth Sleepiness Scale	11.6	6.7
Total MCA (cm^2) before decongestion	1.15	0.29
Total MCA (cm^2) after decongestion	1.37	0.30
Decongestion effect (%) [2]	22.1	18.4

Total MCA = minimum cross-sectional area of the nasal cavity (sum of right and left sides) measured by acoustic rhinometry, [1]measured at the cricoid level, [2]relative decongestion effect on total MCA measured by acoustic rhinometry (%).

The patients were instructed not to take any drugs that might influence sleep and not to ingest alcohol the day before the study nights. The patients were informed about the study objectives and gave written informed consent to participate. The study was conducted in accordance with the Declaration of Helsinki and was approved by the local Ethics Committee.

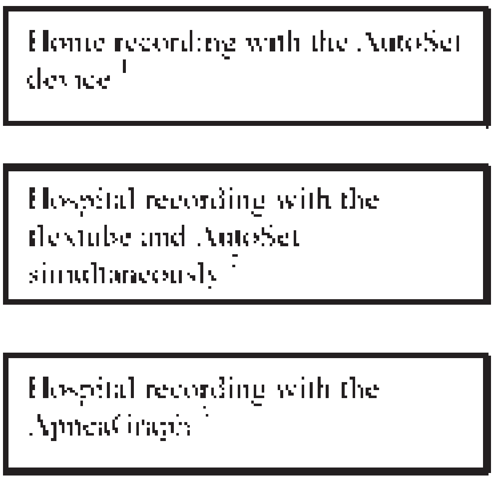

Figure 1. The subjects were investigated on three different nights. The first nights – baseline - recording[1] was performed in the patient's home using AutoSet® (ResMed). The second recording[2] was performed in hospital using flextube reflectometry and AutoSet® simultaneously. The third recording[3] consisted of a study in hospital with ApneaGraph® (ScanMed).

Study design

The study consisted of 3 recording nights (Figure 1). The patients were studied using AutoSet® (ResMed, North Ryde, Australia), which is a diagnostic system based on the respiratory flow/time relationship as measured by pressure variations through nasal prongs. The patients were also studied by flextube reflectometry (RhinoSleep®, RhinoMetrics, Lynge, Denmark), which uses the method of sound reflections in a flexible tube inserted into the nose, pharynx and oesophagus. Finally the patients were studied by ApneaGraph® (ApneaGraph®, Drammen, Norway), which is a diagnostic system, based on continuous measurement of upper airway pressure at 3 levels in addition to oesophageal pressure and airflow.

The longest period with good quality data (readable signals from all sensors) from each of the recording systems was available for analysis. Periods of recording containing snoring and repetitive breathing pauses were considered to indicate sleep, and these periods were subsequently analysed.

We compared the number of flextube narrowings per hour recording with the RDIs determined by the ApneaGraph®.

The percentage of retropalatal flextube narrowing of the total narrowing (the sum of the retropalatal and retrolingual narrowing) was calculated. We also determined the percentage of retropalatal ("upper") obstructive apnoeas and hypopnoeas of the total number ("upper", "intermediate" and "lower" obstructive apnoeas and hypopnoeas) found by the pressure-recording device (ApneaGraph®). The percentage of retropalatal narrowing determined by the flextube was subsequently compared with the percentage of retropalatal events found using the pressure catheter.

The effect on RDI caused by the insertion of the flextube was assessed by comparing – baseline - RDIs measured by AutoSet® in the patient's home with RDIs obtained by the AutoSet® at hospital with the flextube inserted.

The effect on RDI caused by the presence of the pressure catheter was likewise assessed by comparing – baseline - RDIs measured by AutoSet® in the patient's home with RDIs measured in hospital by the ApneaGraph®.

It was not possible to perform simultaneous studies with the AutoSet® system and the ApneaGraph® system because the thermistor of ApneaGraph® and the nasal prongs of the AutoSet® could not be in position at the same time. Neither was it possible to perform simultaneous studies with a flextube and a pressure catheter because it was intolerable for the patients to have these inserted at the same time.

During the investigations in the hospital the body position was monitored using a mercury gauge sensor and we observed for movement artefacts by an infrared camera. Analysis of the sleep recordings was blinded.

Acoustic reflectometry

The acoustic reflectometry system (SRE2100, RhinoSleep® version 3.0.3.43, RhinoMetrics, Lynge, Denmark) has been described previously (Faber et al. 2001a; Faber et al. 2001b). It consisted of a portable computer and a miniprobe; a minor, light metal rod (10 cm and 70 g) attached to a flexible tube (RhinoFlex® Tube) made of PVC. The diameter of the flextube was 5.2 mm. The flextube was closed at the distal end.

The flextube reflectometry set up is explained in Figure 2. The probe generated a noise signal and measured the reflected sound using a microphone. When the soft palate, the tongue, or other structures of the pharynx narrowed the flextube, its cross-sectional area decreased. This resulted in a reflection of the sound from the narrowed level. The software provided information concerning the internal cross-sectional area of the flextube at various distances and determined the number, location and duration of flextube narrowings.

Flextube narrowings, which resulted in a reduction of the cross-sectional area of the flextube of 16 % or more for at least 10 seconds were scored as obstructive events. This definition was applied after preliminary analyses of OSAS patients because area reductions of the flextube of 16% or more were typically observed during obstructive apnoeas and hypopnoeas detected by polysomnography (Faber et al. 2001a). We did not observe flextube area reductions greater than 25% in any of the subjects during apnoeas and hypopnoeas. During kinking of the flextube, however, area reductions greater than 25 % did occur. The cross-sectional area reduction of the flextube was occasionally below 16% during short pauses in flextube narrowings lasting 10 seconds or longer. The software automatically detected these short pauses. A pause of 1 second or less was accepted during flextube narrowings in vivo because we have noticed using magnetic resonance imaging that such pauses often occurred during apnoeas (Faber et al. 2001a). Using pressure-recordings it has also been demonstrated that during apnoeas swallowing and vigorous inspiratory efforts occur, interrupting the apnoeas (Tvinnereim and Miljeteig, 1992). We decided not to accept pauses during flextube narrowings in investigations if the mean duration of flextube events exceeded 100 seconds (Faber et al. 2001a). Using these scoring criteria, all the flextube recordings were automatically scored by the computer.

The narrowings were divided into 2 groups depending on their localization: retropalatal narrowings (from the posterior border of the septum to 4.7 cm below) and retrolingual narrowings (from 4.7 to 9 cm below the posterior border of the septum). These distances were measured from the posterior border of the nasal septum to the lower border of the soft palate (retropalatal level) and from the lower border of the soft palate to the oesophageal inlet (retrolingual level). The distances were determined in a previous study by fiberoptic measurements on 100 adult patients consecutively referred to our sleep centre for snoring and sleep apnoea (Faber et al. 2001a). The mean cross-sectional area reductions of the flextube during obstructive events of the retropalatal and retrolingual parts of the flextube were calculated by the software. The retropalatal narrowing as percentage of the total narrowing (sum of retropalatal and retrolingual narrowing) during obstructive events provided the pharyngeal level distribution (Figure 3).

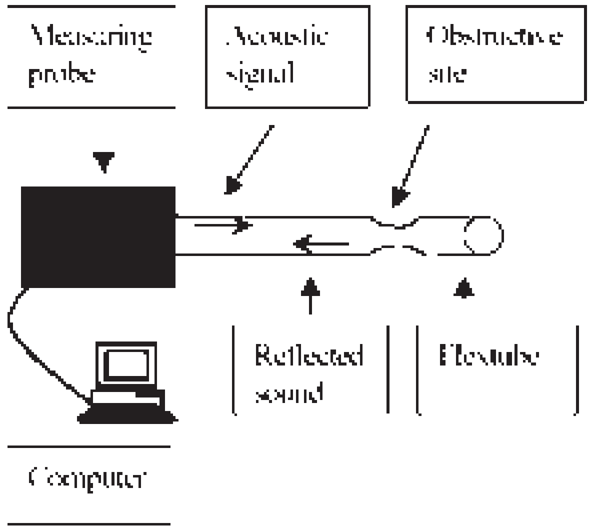

Figure 2. The flextube reflectometry system. A continuous white band noise was generated in the probe and sent into the flextube. The flextube was inserted into the nose, pharynx and oesophagus. When the flextube was compressed during obstructions the noise was reflected. A microphone in the probe recorded the reflected sound. The distance to the obstructive site and the duration of obstructions was calculated by the measuring system and graphically illustrated by the software.

The distance from the nostrils to the posterior border of the nasal septum was determined by endoscopy in each patient. The flextube was fixed to the nose and cheek with the aid of adhesive tape and the 0 point of the flextube was placed exactly at the posterior border of the nasal septum. Xylocain spray was applied to the oropharynx and nasal cavity before insertion of the flextube. The flextube was advanced slowly while the patients drank some water.

Upper airway pressure-recordings by micro transducers

Micro transducers mounted in a catheter connected to a datalogger (ApneaGraph®, MRA Type 102, Drammen, Norway) obtained pressure-recordings. The catheter had a diameter of 2.4 mm and contained 4 transducers, which were semiconductor strain gauges steamed onto a membrane.

The pressure transducers were calibrated individually at atmospheric pressure and at 20 cm H_2O. The calibration was performed immediately before the catheter was inserted into the airway. Xylocain spray was applied to the oropharynx and nasal cavity before insertion of the catheter. The catheter was advanced slowly while the patients drank some water. The transducers were positioned in the middle part of the oesophagus (sensor number 0), at a level just above the vocal cords (sensor number 1), at the base of the tongue (sensor number 2) and in the epipharynx (sensor number 3). A guide mark was located

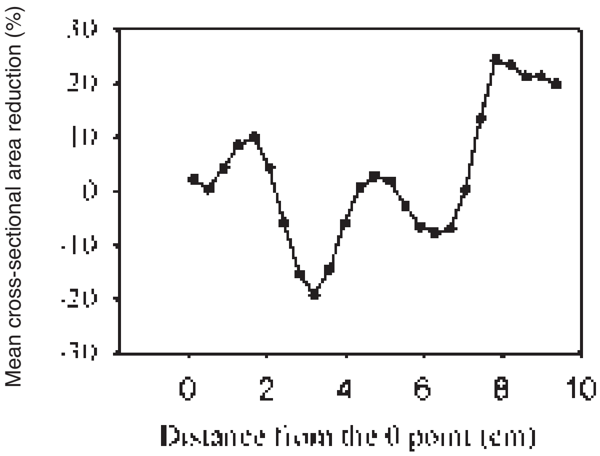

Figure 3. The mean cross-sectional area reduction of the flextube during obstructive events at various distances from the 0 point of the flextube. This person demonstrated a maximum flextube area reduction (10%) at the retropalatal level 1.7 cm from the 0 point during obstructive events. The maximum flextube area reduction (24 %) at the retrolingual level was found 7.8 cm from the 0 point during obstructive events. Consequently the maximum narrowing at the retropalatal level was 29% of the sum of the maximum narrowing at the retropalatal and retrolingual levels during events (10/(10+24)). The dotted line represents a reduction of the cross-sectional area of the flextube of 16 %. Flextube narrowings, which resulted in a reduction of the cross-sectional area of the flextube of 16 % or more for at least 10 seconds were scored as obstructive events.

22.5 cm from the tip of the catheter. This guide mark was placed at the lower edge of the soft palate tip to secure correct placement. The catheters were fixed to the nose with adhesive tape. Three thermistors mounted in a plate were positioned at the upper lip to allow measurements of nasal and oral airflow. The oxyhemoglobin saturation level (Sao2) was measured by pulse oximetry using a finger probe (Nonin® Pulse Oximeter, Model 8500 M, Nonin Medical, Minneapolis, MN, USA). The data-logger and the pulse oximeter were placed in pouches fixed on the upper abdomen. The device was programmed to start automatically at midnight and recorded data for 6 hours.

The recordings were hand-scored manually by the same observer using a high-resolution screen for determination of the RDI. An apnoea was detected if there was a cessation of airflow lasting for 10 seconds or more. Hypopnoea detection required that the thermistor signals were below 70% of baseline for at least 10 seconds.

The number of "upper" (retropalatal) and "intermediate" and "lower" obstructions (obstructive apnoeas and hypopnoeas) was calculated automatically by the ApneaGraph® software. Obstructions were defined as "upper" (retropalatal) if the principal pressure gradient was between sensor number 2 and sensor number 3. "Lower" obstructions were detected if the largest pressure gradient was between sensor number 0 and sensor number 1. "Intermediate" obstructions were detected if the largest pressure gradient was between sensor number 1 and sensor number 2 of the pressure catheter.

Detection of apnoeas and hypopnoeas by pressure fluctuations in the nares

We used a portable diagnostic system (AutoSet®, version 3.03, ResMed®, North Ryde, Australia) to detect apnoeas and hypopnoeas at baseline by performing home recordings. We also used the AutoSet® device during the flextube reflectometry recordings in hospital. The AutoSet® device relies on nasal pressure fluctuations in the anterior nares. The device detects inspiratory airflow changes at the nares using nasal prongs. The recordings were hand-scored manually on a high-resolution screen by the same observer. Hypopnoeas were defined as a reduction below 70% of baseline nasal pressure fluctuations for at least 10 seconds. Apnoeas were scored if there was a cessation of nasal pressure fluctuations for at least 10 seconds.

Statistical analysis

Means and standard deviations (SD) were used for descriptive purposes. To compare means we used paired t-tests. Correlations between AutoSet® and ApneaGraph® and flextube reflectometry results were calculated by the Spearman´s rank test. Statistical analyses were carried out using SPSS® for windows, version 9.0.0. Significance was accepted at $p<0.05$.

RESULTS

The flextube reflectometry procedures and the pressure catheter recordings were accompanied by only minimal discomfort. None of the examinations had to be discontinued due to inconvenience from the flextube or the pressure catheter. There were no complications, including nasal bleeding or mucosal tears.

Sleep study results

The mean duration (SD) of the flextube narrowings for all patients calculated by the software was 37.4 (15.9) seconds.

The mean (SD) percentage of the total flextube measurement time for all patients that was used for analysis was 61.4% (26.0%). This time included periods with readable signals and snoring and repetitive breathing pauses indicative of sleep.

The mean (SD) RDI per hour recording found using AutoSet® at home, AutoSet® with the flextube inserted in hospital, the pressure catheter device (ApneaGraph®) in hospital and the mean (SD) number of flextube narrowings per hour recording in hospital are shown in Table 2.

Flextube narrowings per hour versus RDI by the ApneaGraph®

The mean (SD) number of flextube narrowings per hour recording was 50.2 (20.4) and the mean (SD) RDI determined by the ApneaGraph® was 45.7 (20.2). The mean difference (SD) between the number of flextube narrowings per hour recording and the RDIs determined by the ApneaGraph® was 4.5 (15), which was not statistically significantly different from

0 (p = 0.24, t-test).
There was a statistically significant correlation between the two sets of data (Spearman´s correlation coefficient r = 0.68, p=0.002, n = 17, Figure 4).

Table 2. Results of the sleep studies (n = 17).

	Mean	SD
RDI at home by AutoSet® 1	47.1	21.9
RDI by AutoSet® with flextube inserted 2	51.3	19.7
Flextube narrowings per hour recording 2	50.2	20.4
RDI by pressure catheter (ApneaGraph®) 3	45.7	20.2

The first study was performed at home using the AutoSet® device without flextube or pressure catheter inserted 1. The second study was performed in hospital using AutoSet® and the flextube device simultaneously 2. The third study was performed in hospital with a pressure catheter inserted (ApneaGraph®) 3. RDI = respiratory disturbance index (apnoeas and hypopnoeas per hour recording).

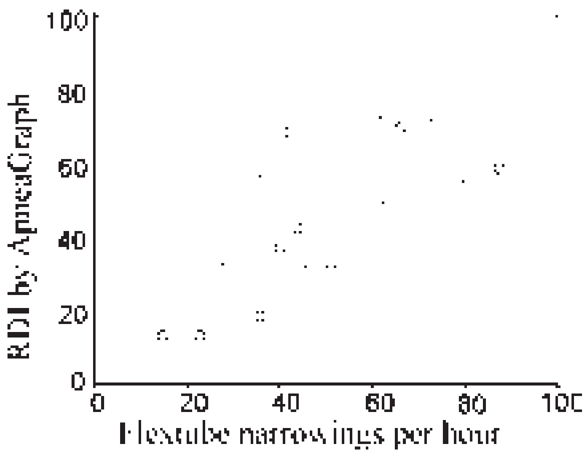

Figure 4. Scatter plot of the relationship between the number of flextube narrowings per hour recording and the RDIs determined by the ApneaGraph®. The measurements were performed in hospital on the same 17 patients on two different nights.

Level distribution by flextube reflectometry and pressure-recordings
The mean (SD) percentage of retropalatal narrowing of the total narrowing (retropalatal and retrolingual narrowing) measured by flextube reflectometry was 42.3% (41.5%). The mean (SD) percentage of "upper" (retropalatal) obstructive apnoeas and hypopnoeas of the total number ("upper", "intermediate" and "lower" obstructions) measured by the pressure-recording device (ApneaGraph®) was 57.3% (33.9%). There was no statistically significant correlation between the two sets of data (Spearman´s correlation coefficient r = 0.24, p=0.36, n = 17, Figure 5).

Four subjects had almost exclusively (98.6% to 100%) retropalatal narrowing by the flextube method and these subjects had predominantly (68.8% to 100%) retropalatal obstructive apnoeas and hypopnoeas when investigated using the pressure-recording system (ApneaGraph®) as seen in Figure 5.

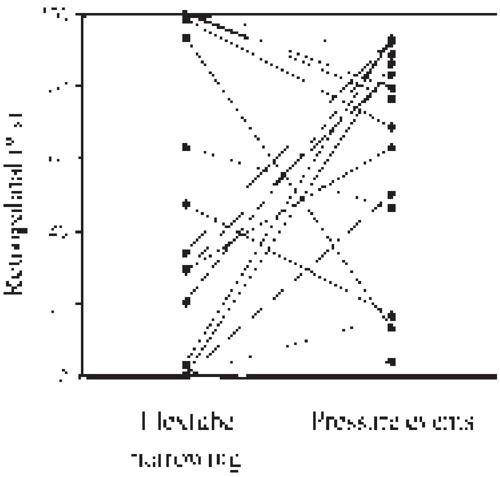

Figure 5. Percentage retropalatal of total flextube narrowing (sum of retropalatal and retrolingual narrowing) during obstructive events versus the percentage of retropalatal obstructive apnoeas and hypopnoeas of the total number of pressure events ("upper", "intermediate" and "lower"). N = 17, measurements were performed on two different nights.

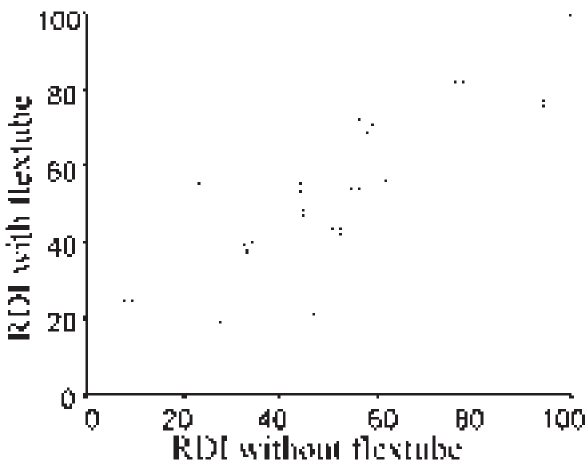

Figure 6. Scatter plot of the relationship between the RDIs determined by the AutoSet® system in hospital with a flextube inserted and the RDIs determined by the AutoSet® system at home without a flextube inserted. N = 17, measurements were performed on two different nights.

Effect of the flextube and pressure catheter on RDI
The mean difference (SD) between the RDIs determined by AutoSet® without a flextube inserted and the RDIs by AutoSet® with a flextube inserted was 4.3 per hour recording (14.4), which was not statistically significantly different from 0 (p = 0.24, t-test). There was a statistically significant correlation between the two sets of data (Spearman´s correlation coefficient r = 0.79, p<0.001, n = 17, Figure 6).
The mean difference (SD) between the RDIs determined by the AutoSet® at home and the RDIs found in hospital by the ApneaGraph® was 1.3 (16.0), which was not statistically signifi-

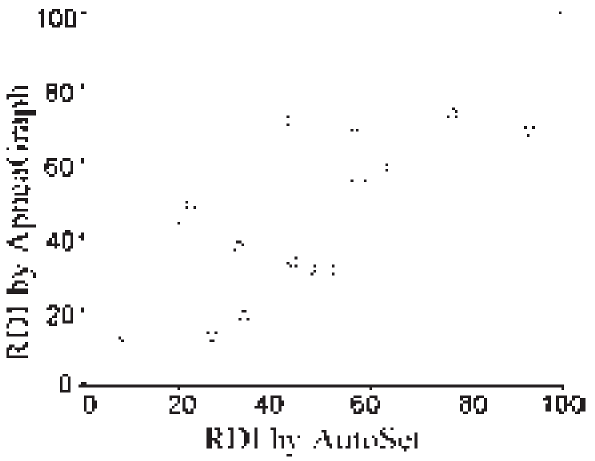

Figure 7. Scatter plot of the relationship between the RDIs determined by the pressure-recording device (ApneaGraph®) in hospital versus the RDIs determined by the AutoSet® system at home without a flextube or a pressure catheter inserted. Measurements were performed on two different nights, N = 17.

cantly different from 0 ($p = 0.74$, t-test). There was a statistically significant correlation between the two sets of data (Spearman's correlation coefficient $r = 0.68$, $p=0.003$, Figure 7).

DISCUSSION

In this study we compared flextube reflectometry with pressure catheter recording for determination of the obstructive level distribution and for determination of the severity of sleep disordered breathing. There was no statistically significant correlation between the percentage of retropalatal narrowing of the total narrowing (retropalatal and retrolingual narrowing) measured by flextube reflectometry and the percentage of "upper" (retropalatal) obstructive apnoeas and hypopnoeas of the total number ("upper", "intermediate" and "lower" obstructions) measured by the ApneaGraph®.

We also compared the number of flextube narrowings per hour recording with the RDIs found using the ApneaGraph®. The mean difference was not statistically significantly different from 0.

To reduce the risk of bias in the determination of the predominant obstructive level we excluded 4 patients with very few obstructive events during the pressure catheter investigation (less then a total of 20 events per recording).

In a previous study (Faber et al. 2001a) we found a statistically significant correlation between the number of flextube narrowings per hour of sleep and the number of obstructive apnoeas and hypopnoeas per hour of sleep determined by PSG (Spearman's correlation coefficient $r = 0.79$, $p < 0.001$, $n = 21$). The ApneaGraph® has been compared to PSG by Tvinnereim et al. (1995) who analysed 200 respiratory events identified one-by-one from PSGs. They found a statistically significant agreement between PSG and pressure catheter recordings (kappa = 0.89). These studies (Faber et al. 2001a; Tvinnereim et al. 1995) confirm that the flextube method and the pressure catheter method both provide results that are comparable to PSG. Consequently it was expected that the number of flextube events and pressure catheter events per hour recording would correlate in a statistically significant way, which was also the case.

It is a limitation of this study that we analysed only periods where snoring or repetitive breathing pauses indicated sleep. The diagnostic devices used in the study do not record neurophysiologic data necessary to characterize sleep stages (electroencephalography, electrooculography and electromyography).

Discrepancies between the primary obstructive levels determined by the flextube method and by the pressure catheter method were expected due to diverging principles behind determination of the level distribution applied by the two methods. The retropalatal and retrolingual levels were defined in different ways using the flextube reflectometry method and pressure catheter method. Flextube narrowings were defined as "retropalatal" when they were located between the posterior border of the nasal septum and 4.7 cm below and defined as "retrolingual" when they were located between 4.7 cm and 9 cm below the posterior border of the nasal septum. This is in contrast to the definitions used by the ApneaGraph®, which detected "upper" (retropalatal) obstructions when the principal pressure gradient was between sensor number 2 and sensor number 3. "Lower" obstructions were detected if the largest pressure gradient was between sensor number 0 and sensor number 1. "Intermediate" obstructions were detected if the largest pressure gradient was between sensor number 1 and sensor number 2 of the pressure catheter. In order to compare the level distribution found by the flextube device and the pressure catheter device the mean (SD) percentage of retropalatal narrowing of the total narrowing (retropalatal and retrolingual narrowing) measured by flextube reflectometry was compared to the mean (SD) percentage of retropalatal obstructive apnoeas and hypopnoeas of the total number ("upper", "intermediate" and "lower" obstructions) measured by the pressure-recording device (ApneaGraph®). The discrepancy between these definitions may cause bias because the upper airway anatomy is variable.

The pressure catheter device only provides information regarding the most proximal obstruction during an obstructive event. The flextube device on the other hand provides information regarding the whole length of the flextube during the entire obstructive event. Differences in sleep stage distribution and sleep position during the two different nights may also have contributed to the discrepancies in relative level distribution.

It is a limitation of the present study that a gold standard for the determination of the predominant obstructive level during obstructive events fails to be identified. Accordingly, the discrepancy between flextube reflectometry and multiple pressure-recordings indicates neither inferiority nor superiority of the flextube device. Further investigations are necessary to improve existing methods and to develop new techniques in search of a gold standard for obstructive level determination.

A number of investigations have been performed to establish the most common level of obstructive predominance in OSAS patients. Rollheim et al. used multitransducer pressure catheter measurements during sleep on 24 OSAS patients and found that the mean (95% CI) percentage of retropalatal obstructive events was 50.8% (37.5-64.0%) (Rollheim et al. 1997).

Woodson et al. also used a multitransducer pressure catheter in their study of 12 OSAS patients. The initial site of obstruction was retropalatal in 9 patients (75%) and retrolingual in 3 (25%) (Woodson and Wooten, 1992).

Croft et.al. used a fiberoptic endoscope during drug-induced sleep and recorded the sites of obstruction in 56 patients. They found retropalatal collapse in 18 patients (32%) and multisegment collapse in 31 patients (55%) and simple palatal snoring in 7 patients (13%) (Croft and Pringle, 1991). In the present study of 17 patients we found that the mean percentage of retropalatal narrowing measured by flextube reflectometry was 42.3%. The mean percentage of retropalatal obstructive apnoeas and hypopnoeas measured by the pressure-recording device (ApneaGraph®) was 57.3%.

In conclusion data from these studies using various diagnostic methods suggest that OSAS patients have varying patterns of narrowing or collapse of the pharynx.

The level of obstructive predominance depends on the specific population and possibly the sleep position (Penzel et al. 2001) and sleep architecture (Boudewyns et al. 1997; Okada et al. 1996) during the specific night. Rollheim et al using pressure catheters found that with increasing obesity, there seems to be a shift to a lower level of obstruction, which may explain the varying results in different studies (Rollheim et al. 1997).

The number of flextube narrowings per hour recording and the level distribution of flextube narrowing were determined by automatic analysis software in the present study. We have previously studied the flextube system by manual scoring of recordings and for that reason we found it necessary to assess the flextube software independently of manual analysis.

The RDIs by the ApneaGraph® and the AutoSet® device were determined by hand-scoring of pressure and airflow tracings because it has been demonstrated in a previous study that hand-scoring of recordings from screening devices for OSAS results in a better agreement with PSG than automatic scoring (Koziej et al. 1994).

One problem associated with both flextube measurement and pressure catheter recording during sleep is the nuisance associated with the presence of a flextube or a pressure catheter. The insertion of a flextube or a pressure catheter may affect the patients sleep and consequently influence the number and obstructive level of apnoeas and hypopnoeas. However, in the present study the flextube and pressure catheter did not influence the mean RDI per hour recording compared with home studies without a flextube or pressure catheter. In our prior study the flextube did not interfere with sleep efficiency, central apnoeas per hour of sleep, mixed apnoeas per hour of sleep, hypopnoeas per hour of sleep, EEG arousals per hour of sleep, REM latency, percentage stage 2 non-REM sleep, percentage stage 3 and 4 non-REM sleep or minimum Sao2. Flextube measurement was associated with a minor but statistically significant decrease in the total sleep time and percentage REM sleep and an increase in percentage stage 1 non-REM sleep, the number of obstructive apnoeas per hour of sleep and the RDI (Faber et al. 2001a), but the clinical significance of these minor changes is doubtful.

CONCLUSION

This study suggests that flextube reflectometry and pressure catheter recordings may provide valuable information regarding the level distribution of upper airway obstructions during sleep. There was no statistically significant correlation between the percentage of retropalatal narrowing of the total narrowing (retropalatal and retrolingual narrowing) measured by flextube reflectometry and the percentage of retropalatal obstructive apnoeas and hypopnoeas of the total number (retropalatal and retrolingual) measured by ApneaGraph®. Further investigations are necessary to improve existing methods and to develop new techniques in search of a gold standard for obstructive level determination.

The flextubes and the pressure catheters were associated with only minimal discomfort

REFERENCES

1. Boudewyns AN, Van de Heyning PH, De Backer WA (1997) Site of upper airway obstruction in obstructive apnoea and influence of sleep stage. Eur Respir J 10: 2566-2572.
2. Bridgman SA, Dunn KM (2000) Surgery for obstructive sleep apnoea [Cochrane Review]. The Cochrane Library
3. Croft CB, Pringle M (1991) Sleep nasendoscopy: a technique of assessment in snoring and obstructive sleep apnoea. Clin Otolaryngol 16: 504-509.
4. Faber CE, Hilberg O, Jensen FT, Norregaard O, Grymer L (2001a) Flextube reflectometry for determination of sites of upper airway narrowing in sleeping obstructive sleep apnoea patients. Respir Med 95: 639-648.
5. Faber CE, Grymer L, Norregaard O, Hilberg O (2001b) Flextube reflectometry for localization of upper airway narrowing - a preliminary study in models and awake subjects. Respir Med 95: 631-638.
6. Fujita S, Conway W, Zorick F, Roth T (1981) Surgical correction of anatomic abnormalities in obstructive sleep apnea syndrome: uvulopalatopharyngoplasty. Otolaryngol Head Neck Surg 89: 923-934.
7. Koziej M, Cieslicki JK, Gorzelak K, Sliwinski P, Zielinski J (1994) Hand-scoring of MESAM 4 recordings is more accurate than automatic analysis in screening for obstructive sleep apnoea. Eur Respir J 7: 1771-1775.
8. Okada T, Fukatsu H, Ishigaki T, Yasuma F, Kayukawa Y (1996) Ultra-low-field magnetic resonance imaging in upper airways obstruction in sleep apnea syndrome. Psychiatry Clin Neurosci 50: 285-289.

9. Penzel T, Moller M, Becker HF, Knaack L, Peter JH (2001) Effect of sleep position and sleep stage on the collapsibility of the upper airways in patients with sleep apnea. Sleep 24: 90-95.
10. Rollheim J, Osnes T, Miljeteig H (1997) The relationship between obstructive sleep apnoea and body mass index. Clin Otolaryngol 22: 419-422.
11. Rollheim J, Osnes T, Miljeteig H (1999) The sites of obstruction in OSA, identified by continuous measurements of airway pressure and flow during sleep: ambulatory versus in-hospital recordings. Clin Otolaryngol 24: 502-506.
12. Sher AE, Schechtman KB, Piccirillo JF (1996) The efficacy of surgical modifications of the upper airway in adults with obstructive sleep apnea syndrome. Sleep 19: 156-177.
13. Tvinnereim M, Mateika S, Cole P, Haight J, Hoffstein V (1995) Diagnosis of obstructive sleep apnea using a portable transducer catheter. Am J Respir Crit Care Med 152: 775-779.
14. Tvinnereim M, Miljeteig H (1992) Pressure recordings - a method for detecting site of upper airway obstruction in obstructive sleep apnea syndrome. Acta Otolaryngol Suppl 492: 132-140.
15. Woodson BT, Wooten MR (1992) A multisensor solid-state pressure manometer to identify the level of collapse in obstructive sleep apnea. Otolaryngol Head Neck Surg 107: 651-656.

Christian Emil Faber, MD
Henriettevej 56
DK-5000 Odense C
Denmark

Tel: +45 - 66 11 41 60
Fax: +45 - 65 91 68 81
E-mail: c.e.faber@dadlnet.dk