Many patients with obstructive sleep apnea syndrome (OSAS) receiving continuous positive airway pressure (CPAP) complain of leaky masks or too high pressure during expiration. C-Flex is a breathing mode with a constant CPAP pressure during inspiration and a reduced pressure during expiration. We compared the leakage data between CPAP and C-Flex and their influence on patients’ compliance. Thirty patients (22 men, 8 women, aged 55.4 ± 11.7 yr, BMI 32.0 ± 7.4 kg/m²) with polysomnographically diagnosed OSAS got a CPAP or C-Flex therapy in a randomized double-blind and cross-over design. After 6 weeks, an adjustment to the other mode followed. Leakage data were sampled during all polysomnographic examinations. Twelve patients dropped out of the study (7 after C-Flex, 5 after CPAP), 4 of them gave up CPAP therapy completely (2 after CPAP, 2 after C-Flex). The leakage in CPAP mode was 27.5 ± 11.5 l/min and in C-Flex mode 28.0 ± 10 l/min (ns). The average nightly use in CPAP mode was 350.0 ± 70.2 min and in C-Flex mode 347.0 ± 70.8 min (ns). In the final decision of therapy, 9 patients chose C-Flex and 4 patients CPAP (P=0.001). Five patients had no preference regarding the therapy mode. There is no difference in leakage and compliance between CPAP and C-Flex. But significantly more patients decided for a therapy with the C-Flex mode. There must be other unknown factors that influence the decision for the mode of therapy.

Key words: C-Flex, compliance, continuous positive airway pressure, mask leakage, obstructive sleep apnea syndrome

INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is defined as a repetitive collapse of the upper airways during sleep, leading to heavy snoring, hypopnea or apnea, with
corresponding oxygen desaturations while respiratory effort persists. Respiratory disorders are followed by arousals with consecutive sleep fragmentation. The major clinical symptoms resulting from OSAS are heavy snoring, apneas, or hypopneas during sleep, and excessive daytime sleepiness (1, 2). The prevalence of OSAS is estimated to be between 2-4 % in middle-aged adults (3).

Therapy most commonly begins with a course of continuous positive airway pressure (CPAP). CPAP is the application of a defined continuous positive pressure with a nasal or full face mask in order to prevent the collapse of the upper airways. This therapy is an effective treatment of OSAS and its cardiovascular sequela (4). Many patients with OSAS receiving continuous positive airway pressure complain of leaky masks or too high pressure during expiration. This may lead to short usage patterns and frequent awakenings with sleep fragmentation and occasional discontinuation of CPAP-therapy.

C-Flex is a breathing mode with a constant CPAP pressure during inspiration and a reduced pressure during expiration. The pressure decreases depending on the expiratory flow and increases in the last phase of expiration to prevent upper airways’ collapse. The relief pressure varies on the breath-to-breath basis, depending on the actual patient airflow. Prior to the end of expiration and start of each inspiration it returns to the prescribed CPAP pressure.

Studies have shown that C-Flex is an effective method to treat OSAS and is comparable to CPAP (5, 6). Furthermore some studies have shown that there is a tendency for better treatment adherence or a significantly better compliance in C-Flex (7-10). Most of these studies were not randomized or blinded. The aim of this study was to compare the leakage data between CPAP and C-Flex and their influence on patients’ compliance in a randomized double-blind trial with cross-over design.

MATERIAL AND METHODS

The study was approved by a local Ethics Committee. We examined patients suspected of OSAS admitted to our clinic, who gave their written informed consent to participate. The exclusion criteria were severe comorbidity, such as acute or chronic heart failure (NYHA grade 3 or 4), severe COPD, dementia, alcoholism, drug abuse, and age under 18. Thirty patients were recruited (22 men, 8 women, mean aged 55.4 ±11.7 years, mean BMI 32.0 ±7.4 kg/m², mean height 176.1 ±8.1 cm, mean weight 100.0 ±26.1 kg).

All patients underwent overnight polysomnography to assess OSAS. We used a computer-based system (Alice 4, Heinen and Loewenstein, Bad Ems, Germany). Polysomnographic data included electroencephalogram, electrooculogram, electromyogram of the chin and leg muscles, nasal and oral airflow (by thermistors), abdomen and chest movement (by plethysmography), oxygen saturation (by finger pulse oximetry), snoring (by laryngeal microphone), body position, and electrocardiogram. The polysomnographic recordings were scored manually on visual basis by an experienced investigator. Sleep stages and arousals were valued in accordance with the criteria of Rechtschaffen and Kales (11). Apnea was defined as a reduction in airflow of at least 50% compared with baseline for 10 s or more. Hypopnea was defined as a reduction in airflow of at least 20% compared to baseline for 10 s or more. The apnea/hypopnea index (AHI) was calculated as the
number of apneic and hypopneic events per hour of total sleep time. Obstructive sleep apnea syndrome was diagnosed with an AHI of 5 or more apnea/hypopnea per hour.

In a double-blind trial, CPAP or C-Flex titration was performed in the following night by increasing the pressure from 5 cm H\textsubscript{2}O in steps of 1 cm H\textsubscript{2}O (Machine REMstar Pro®, Respironics). After 6 weeks, an adjustment to the other mode followed. Another six weeks later a last polysomnographic recording was performed. The physicians and technicians performing the titration and scoring the polysomnographic data were blinded to the treatment mode which was chosen. The patients were only informed that they would receive two different modes of therapy, but they did not know if they got CPAP or C-Flex.

During all polysomnographic examinations the leakage data were sampled. We used the integrated Fleisch Pneumotachograph of the REMstar Pro® and the Respironics analog Output Modul (AOM). Compliance data (average nightly usage) were read out \textit{via} Smart Card that is integrated in the machine. Treatment adherence was reported as a total number of hours the devices were used at the prescribed pressure per 24-hour period.

All data are presented as absolute mean values ±SD.

### RESULTS

After diagnostic polysomnography, 30 patients were included and randomized to CPAP or C-Flex. There were no significant differences between the two groups in any of the anthropometric data (statistical data not shown). Twelve patients dropped out of the study (7 after C-Flex, 5 after CPAP); 4 of them gave up the therapy completely (2 after CPAP, 2 after C-Flex).

The mean total sleep time for all 30 patients was 326.9 ±46.4 min. The mean percentage of stage S1 sleep was 14.8 ±10%, stage S2 was 47.2 ±11.3%, S3 was 18.6 ±7.9%, and S4 was 4.9 ±6.2%. The mean percentage of rapid eye movement (REM) sleep was 13.7 ±8%. The mean arousal index was 18.7 ±10.7/h. The mean AHI was 35.4 ±24.8/h. The mean minimum oxygen saturation was 79.1 ±7.7% and mean oxygen saturation under 90% was 57.6 ±59.7 min.

Both groups improved in AHI, minimum oxygen saturation, oxygen saturation lower than 90%, and arousal index and REM-sleep (statistical data not shown).

\textit{Table 1.} Polysomnographic data comparing CPAP with C-Flex.

<table>
<thead>
<tr>
<th></th>
<th>CPAP (n=23)</th>
<th>C-Flex (n=25)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TST, min</td>
<td>327.8 ±41.8</td>
<td>309.9 ±60.2</td>
<td>ns</td>
</tr>
<tr>
<td>S1, %</td>
<td>8.9 ±6.1</td>
<td>10.2 ±6.8</td>
<td>ns</td>
</tr>
<tr>
<td>S2, %</td>
<td>37.7 ±10.5</td>
<td>35.3 ±8.1</td>
<td>ns</td>
</tr>
<tr>
<td>S3, %</td>
<td>21.0 ±13.5</td>
<td>25.3 ±10.4</td>
<td>ns</td>
</tr>
<tr>
<td>S4, %</td>
<td>10.2 ±7.8</td>
<td>9.0 ±10.3</td>
<td>ns</td>
</tr>
<tr>
<td>REM, %</td>
<td>21.7 ±8.9</td>
<td>19.5 ±6.7</td>
<td>ns</td>
</tr>
<tr>
<td>Arousal index, events/h</td>
<td>8.9 ±3.5</td>
<td>9.3 ±4.6</td>
<td>ns</td>
</tr>
<tr>
<td>AHI, events/h</td>
<td>5.4 ±4.4</td>
<td>6.2 ±5.0</td>
<td>ns</td>
</tr>
<tr>
<td>min. SaO\textsubscript{2}, %</td>
<td>88 ±4.2</td>
<td>87.7 ±4.1</td>
<td>ns</td>
</tr>
<tr>
<td>SaO\textsubscript{2} &lt;90% TST, min</td>
<td>12.0 ±21.6</td>
<td>12.0 ±31.8</td>
<td>ns</td>
</tr>
</tbody>
</table>
There were no statistically significant differences for any polysomnographic parameters between the two groups treated with CPAP or C-Flex. Table 1 shows polysomnographic data comparing both modes of treatment.

The average nightly use was $350 \pm 70.2$ min and $347 \pm 70.8$ min in the CPAP and C-Flex mode, respectively (Fig. 1A; ns). The leakage was $27.5 \pm 11.5$ l/min and $28 \pm 10$ l/min in the CPAP and C-Flex modes, respectively (Fig. 1B; ns). In the final decision concerning the therapy, 9 patients chose C-Flex and 4 patients CPAP (P=0.001). Five patients had no preference regarding the therapy mode (Fig. 1C; ns).

**DISCUSSION**

The main intention of this study was to compare the leakage data between CPAP and C-Flex and their influence on patients’ compliance. C-Flex is a CPAP option with lower pressure at the start of expiration. The results of this study confirm that C-Flex is as effective as CPAP in the treatment of the obstructive
sleep apnea syndrome. There is no difference between CPAP and C-Flex in terms of respiratory parameters and sleep profile.

The average usage of 5.8 h in both groups was within the usual range reported in the literature (12-14). The difference between the two groups was insignificant (3 min). Some studies show improved compliance with increased nightly use in C-Flex (7, 8). But these studies have not blinded or randomized, so that patients were aware of their respective mode which might lead to some bias concerning the results. Another blinded and randomized study showed no significant difference between CPAP and C-Flex in the duration of nightly use (6).

Comparing leakage and compliance data in our study, there appeared to be no clinically relevant advantage of using the C-Flex technology. There is no objective factor to attain greater treatment adherence. Nevertheless, patients displayed a significant preference for a therapy with the C-Flex mode. Apparently, there are other undefined factors that influence the decision for the mode of therapy. One explanation might be that C-Flex is more comfortable, which subconsciously influences patients' decisions. In that case, patients with lower psychological strain, for example, with a lower AHI, should display a higher compliance for C-Flex. The same study in patients with milder OSAS may have delivered different results. In the literature it is reported that nearly 20% of all patients receiving CPAP complain of a perception of exhaling against a high pressure (15). Thus, it appears plausible that the pressure reduction during expiration is more acceptable for patients with severe OSAS who need a higher CPAP-pressure. We propose that further studies should be undertaken to investigate the advantages of C-Flex.

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