Clinical research

Severe bradyarrhythmias in patients with sleep apnoea: the effect of continuous positive airway pressure treatment

A long-term evaluation using an insertable loop recorder

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Aim In this new era of insertable loop recorders, we studied obstructive sleep apnoea–hypopnoea syndrome (OSAHS) patients in order to evaluate their arrhythmias and the beneficial effect of Continuous Positive Airway Pressure treatment (CPAP), over a long-term period.

Methods and results We enrolled 23 patients (16 men, 50 ± 11 years) with moderate and severe OSAHS. In all patients, an insertable loop recorder capable of monitoring the heart rhythm for 16 months was implanted. Cardiac pauses > 3 s and bradycardic episodes < 40 bpm during a 2-month period before, and for 14 months after, the CPAP application, were noted. In each period, the patients underwent two 24-h Holter recordings. Before treatment, 11 patients (47%) revealed severe cardiac rhythm disturbances, mostly nocturnal. Holter recordings showed disturbances in only 3 (13%) patients (P = 0.039), those in whom the insertable loop device had recorded frequent episodes. Eight weeks after the initiation of treatment, the total number of the recorded episodes tended to decrease while, during the last 6 months of the follow-up, no episodes were recorded.

Conclusion Approximately half of OSAHS patients evidence severe cardiac rhythm disturbances, which are significantly reduced by CPAP. Holter recordings seem unable to precisely describe the incidence of severe brady-arrhythmias and the effect of treatment.

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KEYWORDS
Sleep apnoea;
Cardiac rhythm disturbances;
Insertable loop recorder

Introduction
Sleep apnoea constitutes a major social problem because of its high prevalence and its emerging association with cardiovascular morbidity. Cardiac arrhythmias have been reported in association with obstructive sleep apnoea–hypopnoea syndrome (OSAHS) and mainly sinus arrest, sino-atrial or atrio-ventricular block, while supra-ventricular and ventricular arrhythmias are less frequently found. However, there is great discrepancy between the findings of studies concerning the incidence

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of such arrhythmias.\textsuperscript{7–10} This could be attributed partly to selection bias and to the limited number of patients included in most of those studies, but mainly to the fact that cardiac arrhythmias were evaluated over short time periods of 18–24 h and most often during polysomnography.

The effect of continuous positive airway pressure (CPAP) administration has also been evaluated during short-term monitoring and has been found to eliminate the occurrence of brady-arrhythmias acutely,\textsuperscript{11–14} but our knowledge of the long-term impact of this treatment is limited. Furthermore, conclusions based on short-term ECG monitoring could be misleading because of a possible variation in the appearance of such arrhythmias. Additionally, there is a great inter-individual variability in the number of bradycardic episodes\textsuperscript{6,8} and so far it is not known whether there is also intra-individual variation in the occurrence of such arrhythmias. Previous researchers have proposed\textsuperscript{7} a hypoxia-induced increase in vagal tone as a pathogenetic mechanism, however there are still conflicting results with regard to the question whether these arrhythmias are correlated with the severity of the syndrome or with other clinical factors.\textsuperscript{13,15}

The recently introduced insertable loop recorder – a device capable of long-term ambulatory cardiac rhythm monitoring has proven itself valuable in the investigation of dizzy spells and syncope.\textsuperscript{16}

In this study, we evaluated rhythm disturbances in OSAHS patients before and after CPAP treatment by using this subcutaneously implanted device in order to monitor cardiac rhythm for at least 16 months. We aimed to clarify the incidence of brady- and tachy-arrhythmias, their relation to the severity of the disease, other anthropometric and clinical parameters and whether they exhibit intra-individual variation. Additionally, we investigated the acute and mainly, the long-term impact of CPAP treatment on the occurrence of cardiac rhythm disturbances in such patients.

Methods

The study population consisted of 31 patients with previously diagnosed moderate to severe OSAHS. All patients were recruited consecutively from the Sleep Disorder Unit of our University Hospital.

Study design

Following the diagnosis of OSAHS based on full night polysomnography and a sleep history, an insertable loop recorder device was implanted in patients who had given full consent and who prospectively underwent long-term cardiac rhythm monitoring. During the first 4 months follow-up was carried out on a weekly basis and thereafter on a monthly basis. At the end of the first 2 months the patients were placed under CPAP treatment. In addition, during the first 2 months prior to the initiation of treatment and the first 2 months after, a total of four 24-h Holter recordings were made – two in each period – on random dates.

Before inclusion and after the initial polysomnographic screening, all patients underwent a diagnostic workup that included medical history, physical examination, echocardiography, routine laboratory investigation and a TI201 scintigraphic exercise test for the assessment of myocardial perfusion. Blood gases and lung function tests were also evaluated in each patient. An invasive electrophysiology study was also performed to examine sinus node and atrio-ventricular node function. Exclusion criteria were hypertension, diabetes mellitus, sinus node disease and atrio-ventricular conduction abnormalities, indications of coronary artery disease, dilated or hypertrophic cardiomyopathy, valvular heart disease, history of respiratory failure, history of lung disease that might have led to structural or functional pulmonary dysfunction, or use of cardioactive medication, hypnotics or drugs affecting sleep. The echocardiographic study was repeated at the end of the follow-up period.

The Hospital’s Ethical Committee approved the study and oral and written informed consent was obtained from every patient.

Sleep study and polysomnography scoring

All participants underwent a full night of polysomnography in the sleep laboratory. Monitoring started at 10:30 pm and ended at 6:30 am. Recordings were made with an Alice-4 18 channel polygraph (Alice-4 Respironics, Pittsburgh, PA, USA) and included monitoring of electro-encephalogram (C3/A2, C4/A1 and Cz/Oz), electro-oculogram, genioglossus and anterior tibialis electro-myograms, ECG, oxygen saturation, nasal thermistors and nasal canula pressure transducer, thoracic and abdominal bands, microphone for snoring and body position electrode (all according to the 10-20 International electrode placement system).\textsuperscript{17}

A sleep history was taken and we evaluated daytime sleepiness using the Epworth Sleepiness Scale. Sleep staging was scored visually according to the criteria of Rechtschaffen and Kales\textsuperscript{17} and micro-arousals were defined according to the criteria of Bonnete et al.\textsuperscript{18} Respiratory event analysis and apnoea–hypopnoea index were scored visually and calculated according to international criteria, with hypopnoea manifesting as an adverse of thoraco-abdominal effort of at least 50% with an associated oxygen desaturation of at least 4% and apnoea as a cessation of airflow at the nose and mouth lasting at least 10 s and were classified as obstructive or central on the basis of the presence of paradoxical movements of the rib cage and of the abdomen.

The severity of OSAHS was classified according to the American Sleep Disorders Association criteria as mild, moderate or severe when apnoea–hypopnoea index was between 5 and 15, 15 and 30 and greater than 30, respectively.\textsuperscript{19}

Before the CPAP titration study, all patients received an educational explanation of OSAHS and CPAP treatment by medical staff at the Sleep Disorders Unit and by specialised CPAP nurses and were shown an educational video. All patients underwent mask fitting from a wide range of mask types and spent 30 min becoming acclimatised to CPAP on a bed during the day. At follow-up (per month), the mean nightly run time for each patient’s CPAP machine was calculated from the time clock reading.

Insertable loop recorder implantation, programming and follow-up

The loop recorder implantation took place in the electrophysiology laboratory following standard operating procedures. A mapping procedure was performed during the operation using the insertable loop recorder device with the electrodes facing
the carefully disinfected skin that was wetted with normal saline to increase conductivity. The electrogram was obtained telemetrically, using the programmer’s head protected in a sterile sleeve. Peak to peak amplitudes of P, R and T waves were examined and R/T and R/P ratios were determined, in different positions and orientations in the aforementioned areas. Ideal R/T ratios were ≥ 2:1 and ideal R/P ratios were ≥ 5:1. The device was implanted in the area that provided the best amplitude and ratios.

The initial sensitivity of the device was manually programmed according to the manufacturer’s recommendations. Pause recognition was set to 3 s, while bradycardia threshold was set to 40 bpm, and the devices were programmed to record 1 patient-activated, and the first 14 auto-activated, events. A heart rate greater than 165 bpm for 16 consecutive beats was set to be recognised as tachycardia. Patients were instructed how to activate the device in case of a symptomatic event — palpitation, dizziness or syncope. During the first 4 months the device was interrogated weekly and thereafter monthly.

Twenty four-hour ambulatory Holter monitoring

Continuous ambulatory Holter recorders were attached to the patients using standard procedures, following the manufacturer’s instructions. Two 24-h Holter recordings were obtained during the 2-month period before, and a further two during the 2-month period after, commencement of CPAP treatment. Data analysis was performed after digitisation using the ELATEC analyser V3-03 software (ELA Medical, Paris, France). For data interpretation we used the same cardiac rhythm disturbances criteria programmed for the insertable loop recorder auto-activation.

Statistical analysis

Summary descriptive statistics are expressed as means ± SD (or median and interquartile range (IQR) in case of a skewed distribution) or percent, for continuous and categorical variables, respectively. Continuous baseline parameters were compared between patients with episodes and patients without episodes with the Student’s t test or the Mann–Whitney U test, as appropriate. Categorical variables between these two groups were compared with Fisher’s exact test. Differences in the number of events between smokers and non-smokers were assessed with a Mann–Whitney U test.

The insertable loop recording device-recorded distributions of episodes (pauses, bradycardias) for each patient were assessed over two 8-week periods: the first 8-week period prior to treatment and the second 8-week period immediately after treatment. From these distributions we could examine the weekly variation of (a) the proportion of patients with episodes before and after treatment and (b) the number of episodes. The short-term effect of the treatment was evaluated by comparing the number of episodes per patient for the whole 8-week period before treatment to the number of episodes per patient for the corresponding post-treatment period. The comparison was carried out using the Student’s t test for dependent samples, or the Wilcoxon’s signed rank test, as appropriate.

The longer-term effect of the treatment was also assessed by comparing the number of episodes per patient for the 8-week period prior to treatment with the number of events per patient for each of the six consecutive 2-month periods (one year follow-up) following the 8-week immediate post-treatment period. To determine whether the number of episodes per patient for these seven 8-week periods differed significantly we employed Friedman’s test, as the repeated measures ANOVA assumptions could not be reliably tested.

We also investigated, in an exploratory fashion, the relationship between the number of events with BMI, AHI, ejection fraction and oxygen saturation using simple linear regression and correlation techniques. All statistical tests were two-sided with a 5% level of significance.

Results

A total of 23 (16 men, 50 ± 11 years old) out of 31 consecutively screened patients who met the inclusion criteria had an insertable loop recorder device implanted and were included in the study. Five initially screened patients were excluded, because of coronary artery disease (n = 2), obstructive pulmonary disease (n = 2) and sinus node dysfunction (n = 1) while 3 patients refused to participate in the study. In four patients the systolic blood pressure on initial examination was mildly elevated. However, neither subsequent daily measurements nor ambulatory blood pressure Holter monitoring was indicative of true hypertension, thus these patients were included in the study. Anthropometric and clinical characteristics of the study population are given in Table 1. The total follow-up period was 16 months. Of the study population 83% had severe and 17% moderate OSAHS. The prevalence of smoking in those patients was 22%. No syncopal or pre-syncopal event was described. The ejection fraction, end-systolic and end-diastolic diameters, body mass index and smoking status were not significantly different before and after treatment (P = 0.14, 0.86, 0.08, 0.41, 0.95, respectively).

Prior to commencement of CPAP treatment the insertable loop recorder device in 11 patients (47%) revealed some cardiac rhythm disturbances, which were mostly nocturnal. Five of the patients revealed multiple severe bradyarrhythmic events and frequent pauses (sinus arrest or complete heart block), of which the most serious was a nocturnal episode of complete heart block with ventricular asystole up to 12 s in one patient. Three patients exhibited only severe brady-arrhythmic events and prolonged sinus pauses while in two of the patients three episodes of supra-ventricular tachycardia were recorded. The most noteworthy finding, however, was the large weekly variation of the episodes — either pauses or bradycardias (Fig. 1).

Specifically, before treatment, the weekly interrogation of the insertable loop recorder revealed a percentage of patients with cardiac rhythm disturbances ranging from 13% to 22%, with the average number of weekly episodes per patient ranging from 0.4 to 1.4. Findings during the study of bradycardia episodes were similar, with percentages ranging from 17% to 26% and an average number of weekly episodes ranging from 1 to 1.6 per patient. In Fig. 1 the wide weekly fluctuation in the percentage of patients with episodes is illustrated, while Fig. 2 shows the distribution of the weekly variation of the episodes.

On the other hand, 3 (13%) patients experienced cardiac rhythm disturbances during 48-h ambulatory Holter ECG and ECG monitoring during polysomnography.
These 3 patients had a consistently large number of episodes each week, as recorded by the insertable loop recorder. With Holter ECG monitoring over a short time period we have a small likelihood of detecting highly variable cardiac rhythm disturbances. This high variability means that 48-h Holter recording is probably not the most accurate method for evaluating either the actual incidence of pauses and bradycardias or the therapeutic effect of the CPAP on them.

The beneficial effect of CPAP treatment on reducing rhythm disturbances was manifest 8 weeks following treatment. Of the 23 patients 14 never had any bradycardias and 16 had never had pauses, either before or after treatment. Two patients with no bradycardias before treatment had one episode the first post-treatment week and none thereafter. The median number of bradycardias per patient decreased drastically from 5.5 for the 8-week pre-treatment period to 0.5 for the 8-week period following treatment ($P = 0.028$, Table 2). Of the 7 patients who had pauses during the 8-week pre-treatment period 4 experienced no episodes throughout the...

### Table 1 Pre-treatment characteristics in patients with and without cardiac rhythm disturbances

<table>
<thead>
<tr>
<th></th>
<th>Patients with cardiac rhythm disturbances</th>
<th>Patients without cardiac rhythm disturbances</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>$48\pm9$</td>
<td>$51\pm6$</td>
<td>0.41</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>7/4</td>
<td>7/5</td>
<td>0.99</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>$142\pm13$</td>
<td>$139\pm8$</td>
<td>0.53</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>$81\pm6$</td>
<td>$78\pm8$</td>
<td>0.35</td>
</tr>
<tr>
<td>FEV$_1$ (% predicted)</td>
<td>$101\pm21$</td>
<td>$98\pm23$</td>
<td>0.74</td>
</tr>
<tr>
<td>FVC (% predicted)</td>
<td>$99\pm18$</td>
<td>$97\pm21$</td>
<td>0.80</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>$37\pm5$</td>
<td>$33.2\pm4$</td>
<td>0.06</td>
</tr>
<tr>
<td>AHI (per hour)</td>
<td>$69\pm23$</td>
<td>$53\pm20$</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**Echocardiographic findings**

<table>
<thead>
<tr>
<th></th>
<th>Patients with cardiac rhythm disturbances</th>
<th>Patients without cardiac rhythm disturbances</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF (%)</td>
<td>$61.1\pm3.7$</td>
<td>$62.9\pm3.4$</td>
<td>0.23</td>
</tr>
<tr>
<td>ESD (mm)</td>
<td>$31.5\pm2.9$</td>
<td>$30.3\pm3.5$</td>
<td>0.34</td>
</tr>
<tr>
<td>EDD (mm)</td>
<td>$50.4\pm3.3$</td>
<td>$49.8\pm2.7$</td>
<td>0.25</td>
</tr>
<tr>
<td>DTE (ms)</td>
<td>$204\pm9$</td>
<td>$201\pm10$</td>
<td>0.27</td>
</tr>
</tbody>
</table>

FEV$_1$, forced expiratory volume in one second; BP, blood pressure; FVC, forced vital capacity; BMI, body mass index; AHI, apnoea–hypopnoea index; DTE, deceleration time of early trans-mitral filling wave.
The variability of the weekly distribution of recorded events during the immediate post-treatment period persisted, but was smaller than before; this is another demonstration of the therapeutic effect of CPAP. Sinus pauses and bradyarrhythmic events were reduced and disappeared in 6 patients during the first 2 months of therapy. Five of the patients who initially revealed multiple bradyarrhythmic events and pauses showed a small improvement, which steadily increased, once therapy commenced, indicating the beneficial effect of CPAP treatment in the long-term. Nine of the 11 patients remained totally free of any traceable cardiac arrhythmic event during the 14 months follow-up.

As we see in Table 2 during the 12 months follow up, both the number of pauses and the number of bradycardias continued to decrease rapidly (Friedman’s $P < 0.001$ for both). Six months after treatment there was only one patient with bradycardias and one with pauses. No pauses were detected after the 6-month time point and no bradycardias after the 10-month time point.

The diagnostic capability of the 48-h Holter recording was insufficient to show either the actual incidence of pauses and bradycardias or the therapeutic effect of the CPAP on the arrhythmias. After treatment initiation, one of the patients who had shown cardiac rhythm disturbances before treatment still exhibited bradycardias, while another continued to show pauses.

Supra-ventricular arrhythmias were present to a lesser extent and did not seem to be affected significantly by CPAP treatment. In particular, only 2 patients (8.5%) had an episode of supra-ventricular tachycardia before treatment, one patient had no further episodes of supra-ventricular arrhythmias after the start of CPAP treatment and another patient recorded one episode. One other patient, who had no such tachycardias before treatment, recorded two episodes of supra-ventricular tachycardia after treatment was started.

The patients’ ejection fraction was unrelated to any differences in pauses ($r = −0.33, P = 0.12$) and bradycardias ($r = −0.34, P = 0.11$). However, the number of bradycardic episodes was correlated with body mass index ($r = 0.48, P = 0.02$) and to the oxygen saturation during polysomnography study ($r = −0.443, P = 0.034$), while it tended to be affected by apnoea–hypopnoea index ($r = 0.406, P = 0.055$). Pauses did not show a significant correlation with either of the above factors. The smoking status was also entirely unrelated to either bradycardia or pauses.

### Discussion

In this study we found that patients with moderate or severe OSAHS exhibit frequent episodes of bradycardia and long pauses, either sinus arrest or complete heart block, mainly during sleep. We also found that these bradycardiac episodes and pauses acutely and the results of treatment are maintained and even augmented in the long-term.

It is well known that patients with OSAHS, apart from showing a higher incidence of cardiovascular disorders, also often suffer from cardiac rhythm disturbances such as ventricular arrhythmias and, mainly, episodes of bradycardia and ventricular asystole that sometimes last for longer than 13 s.\(^\text{10}\)

To date, arrhythmias related to OSAHS have been studied using 18–24 h Holter recordings which are generally made during the polysomnography study that these patients undergo. The incidence of arrhythmias reported in these studies has varied widely — up to 78% — in patients with a moderate or severe degree of OSAHS. Thus, the exact incidence of these significant tachycardiac and bradycardiac episodes and pauses acutely and the results of treatment are maintained and even augmented in the long-term.

In our study, we recorded bradyarrhythmic episodes and pauses in approximately half of patients with moderate and severe OSAHS before the initiation of CPAP treatment.

### Table 2

Descriptive statistics of bradycardias and pauses before and after treatment, in 8-week time intervals

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Bradycardias</th>
<th>Pauses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>IQR</td>
</tr>
<tr>
<td>8 Weeks before</td>
<td>5.50</td>
<td>53.75</td>
</tr>
<tr>
<td>treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Weeks after</td>
<td>0.50</td>
<td>2.75</td>
</tr>
<tr>
<td>treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–4 Months</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>5–6 Months</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>7–8 Months</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>9–10 Months</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>11–12 Months</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>13–14 Months</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

IQR, Interquartile range = difference between the 75th and 25th percentiles.

The 25th percentile was equal to 0 throughout the observation period. In this case the IQR is equal to the 75th percentile.
To our knowledge, the largest study is that of Guilleminault et al.\textsuperscript{10}, which included 400 patients and found bradycardic arrhythmias in 18%. Becker et al.\textsuperscript{9}, in a study with 239 patients, reported heart block in approximately 20% of patients with severe OSAHS and in 7.5% of an unselected group of patients with OSAHS.

The significant discrepancies among the existing data may be explained by the fact that the studies are not comparable: they show important differences in design, in patient selection and in the techniques to establish the diagnosis and severity of the OSAHS, as well as in the criteria used to define cardiac conduction disturbances. Our study, in contrast to previous investigations, included patients with no other cardiovascular diseases and employed well-defined inclusion and exclusion criteria to avoid a secondary underlying cause for our findings.

Furthermore, our own observation that the cardiac rhythm disturbances show enormous intra-individual variability in the long-term could be another explanation for the wide variations in the findings of previous studies. This means that the 24-h or even 48-h Holter monitoring used in earlier studies is incapable of demonstrating the real incidence of arrhythmias. Assuming that the prevalence of OASHS in the general population is about 20%,\textsuperscript{1,2} one would need approximately 700 people in order to estimate that proportion within a 3% margin of error.

The large fluctuations in the incidence of cardiac rhythm disturbances in OSAHS also explain the poor correlation between ambulatory Holter and insertable loop recorder findings. This variability can be attributed in its turn to nightly variations in the sleep state and the degree of apnoeas and hypoxic events characterising the syndrome, which are caused by many exogenous factors, such as nasal congestion, differences in posture and body position, sleep architecture, gender and previous pulmonary status.\textsuperscript{20,21} Our study is the first prospective trial which investigates heart rhythm in patients with OSAHS through continuous long-term ECG monitoring and assesses the credibility of conventional Holter ECG recordings for this aim. We found that there was a very high prevalence of bradycardic episodes and sinus pauses and that most went undetected by 48-h Holter. Ambulatory Holter was able to show abnormalities only in those patients who had very frequent rhythm disturbances, whereas it failed to do so in those whose arrhythmias were not so frequent.

In accordance with previous studies, our own findings show that episodes of bradycardia and sinus pauses occurred mainly during sleep, supporting the belief that the pathophysiology of apnoea—hypopnoea is the triggering factor. According to previous data\textsuperscript{3} we found a correlation between bradycardia and body mass index, apnoea—hypopnoea index, and desaturation level. However, the limited study population does not permit conclusions concerning clinical factors implicated in the severity of arrhythmic events. Previous data have given inconsistent results regarding the relationship of arrhythmias with the severity of sleep apnoea and the reduction of oxygen saturation in the blood.\textsuperscript{10,14,22} Our results are in agreement with Becker et al.\textsuperscript{9}, who found that patients with heart block were significantly more obese and had more severe disease.

Apart from the anthropometric factors that are correlated with the incidence of cardiac rhythm disturbances, most studies have emphasised a reflex increase in vagal tone as a potential mechanism for these episodes, triggered by a combination of hypopnoea and hypoxia. Although the evidence in the literature is inconclusive, vagally mediated pathophysiological mechanisms seem to play a crucial role, rather than structural abnormalities of the conduction system. This is supported by our own experience, in that all patients had normal electrophysiology study findings.

In spite of the multiplicity of published studies, the precise role of apnoeas in the pathogenesis of the presented rhythm abnormalities has not been completely clarified. Although our patients underwent long-term monitoring of cardiac rhythm it was not feasible to perform continuous recording of daily apnoea—hypopnoea index. Given the nightly variability in the severity of OASHS, it would be interesting to know whether the patients who showed no pauses or bradycardia also experienced episodes of sleep apnoea or not.

CPAP has been indicated as a device with the capacity of preventing the upper airway occlusion that occurs in OSAHS by increasing trans-mural pressure in the upper airways. There are previous reports that CPAP treatment has beneficial impact on cardiac rhythm disturbances and reduces the apnoea-associated bradyarrhythmia in up to 80—90% of patients.\textsuperscript{11,14} However, these reports had the same limitations as the studies assessing arrhythmias incidence, since they used short-term recordings, rather than continuous recording using an insertable loop recorder, which could be considered the gold standard for this purpose. In addition, few systematic studies have examined whether the therapeutic result continues in the long-term follow-up of cardiac arrhythmias under CPAP treatment. In particular, Harbison et al.\textsuperscript{13} who reported that significant rhythm abnormalities occurred in 8 of 45 patients and only during the night, observed that CPAP abolished the disturbances to a large extent. A beneficial effect of CPAP treatment on rhythm abnormalities, observed during long-term follow-up, has also been reported.\textsuperscript{11,15} Our data confirm these findings provided that a better tool is used for the long-term monitoring. During the first 4 weeks of CPAP treatment bradycardic episodes and pauses reduced significantly and after that by almost 100%. We believe that the incomplete disappearance of rhythm disturbances during the first 2 months of treatment is mainly due to poor compliance to CPAP and incorrect nasal mask application by some patients. So the gradual disappearance of heart rhythm disturbances was mostly due to the better application and the patients’ “education”, although a continuously accumulative treatment effect could not be excluded. This treatment effect could be attributed to the night-time reduction of parasympathetic activity induced by CPAP application.\textsuperscript{23} Tachycardic episodes were noted to a much lower degree percentage and were not significantly affected by
CPAP treatment. Although the population sample was too small to confirm the validity of this finding, it could have a relationship with the different triggering factors of tachycardias in OSASHS in comparison with bradycardias, i.e., which are mostly related with autonomic nervous system disturbances. Our programming of the device was aimed at detecting only severe ventricular arrhythmias. Thus, the disagreement between our data and those of previous studies that reported ventricular arrhythmias up to 48% is to be expected, given that the majority included much less severe arrhythmias in their data analysis than we did. Furthermore, previous studies included patients with organic heart disease and in particular patients with heart failure, who were excluded from the present study. On the other hand our data are in accordance with a recent study of Roche et al.,15 who also postulated that this syndrome does not result in an increased risk of ventricular arrhythmias.

Limitations

This study did not include a control group, either of OSASHS patients not receiving treatment or of healthy individuals known to exhibit bradycardia episodes during sleep. However, it would be unethical to withhold proper treatment from patients with severe OSASHS or to implant an insertable loop recorder in a healthy person without a clear medical indication.

In addition, the data received about the total number of events, specifically the pauses and bradycardias, could be limited because the maximum capacity of the device is 14 events. Thus, the total may have been under-estimated. However, in only one patient and during 1 week before the initiation of CPAP treatment all memory positions were filled by arrhythmic events.

Conclusions

Patients with a moderate or severe degree of OSASHS exhibit frequent episodes of bradycardia and long pauses during sleep. These events have a significant night-to-night intraindividual variability and their incidence is grossly under-estimated by conventional short-term ECG Holter recordings. The long-term continuous monitoring of rhythm disturbances with the insertable loop recorder confirmed the effectiveness of CPAP treatment in significantly and immediately reducing these rhythm disturbances, while the benefit of the treatment is maintained over the long-term.

References


