Cardiopulmonary coupling analysis: changes before and after treatment with a mandibular advancement device

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Introduction

It seems to clinicians that there are some discrepancies between a subjective improvement of sleep quality and improvements of objective findings in polysomnography with any kind of treatment for obstructive sleep apnea (OSA). Therefore, sleep quality cannot be assessed only by patients' subjective judgment. Though various polysomnographic parameters may be associated with sleep quality, another method to assess the quality of sleep with electrocardiography (ECG) has been proposed. Recently, ECG-based cardiopulmonary coupling (CPC) analysis was developed to evaluate the sleep quality as well as sleep disordered breathing in OSA. The information related to the simultaneous heart rate and respiratory dynamics is readily extractable from a continuous single-lead ECG.

A mandibular advancement device (MAD) is one of main treatment modalities for OSA. The changes of sleep quality have been evaluated using CPC analysis for other treatment modalities, including continuous positive airway pressure and adenotonsillectomy. However, there has been no study based on CPC analysis in treatment with MAD until now.

Aims of this study

The aim of this study was to evaluate the alterations of sleep quality based upon CPC measures in patients with OSA after application of MAD.

Materials & Methods

Subjects

We retrospectively screened 79 patients who underwent in-laboratory full-night polysomnographies before and 3 months after application of a MAD between January, 2011 and September, 2012. Apnea was defined as the complete cessation of airflow for at least 10 seconds. Hypopnea was defined as a substantial reduction in airflow (≥50%) for at least 10 seconds or a moderate reduction in airflow for at least 10 seconds associated with electroencephalographic arousals or oxygen desaturation (≥4%). Exclusion criteria were as follows: significant arrhythmias including atrial fibrillation, low quality data (artifact more than 20% of total sleep time), less than 4 hours of total sleep time, less than 80% of sleep efficiency, patients with combined sleep disorders (i.e. insomnia, narcolepsy), habitual user of sedatives and hypnotics. Finally, a total of 52 patients with OSA were included in this study. All patients were treated only with a MAD. To estimate the sleep quality, we calculated the CPC parameters from each polysomnography. Daytime sleepiness was evaluated with Epworth sleepiness scale (ESS) and subjective sleep quality was assessed with Pittsburgh sleep quality index (PSQI). This study was approved by Seoul National University Bundang Hospital Institutional Review Board (IRB No. B-1210/176-113).

Cardiopulmonary coupling analysis

The CPC was measured on the exported single-lead ECG data using a polysomnography software RemLogic 2.0 CPC analyzer (Embla Systems, San Carlos, CA, USA). Thomas and his colleagues described technical details regarding how to process the data in a previous study. Details of the method have been published and are also available in the online Appendix (www.journalofsleep.org). In briefly, they analyzed the R-R interval series and their associated EDR signal by using Fourier-based techniques and estimated the degree of CPC. The R-R interval time series and EDR signals were first decomposed into a set of sinusoidal oscillations with specific amplitudes and phases at each frequency. If both signals at a given frequency have relatively large oscillation amplitudes, then it is likely that these two signals are coupled with each other. This coupling effect can be measured by computing the cross-spectral power. If two oscillations at a given frequency are synchronized with each other, this synchronizing effect can be measured by computing the coherence of these signals. The CPC analyzer, in accordance with the above-mentioned algorithms, determined the amount and frequency of coupling between EDR and heart rate variability, including high frequency coupling (HFC; 0.1 - 0.4 Hz), low frequency coupling (LFC; 0.01 - 0.1 Hz), elevated low frequency coupling (e-LFC; a subset of LFC) and very low frequency coupling (VLFC; 0.001 - 0.01 Hz).

Statistical Analysis

Data analysis was performed using SPSS (version 18, Chicago, IL). All the values are expressed as means ± standard deviation unless otherwise specified. We used paired t-test to compare the differences of parameters before and after application of a MAD. The Pearson correlation analysis was employed to evaluate the relationship between two continuous variables. A p-value < 0.05 was considered significant.

Results

Table 1. In-laboratory full-night polysomnographic parameters before and with with a mandibular advancement device (MAD) in patients with obstructive sleep apnea.

Table 2. Changes in parameters of cardiopulmonary coupling (CPC) after use of a mandibular advancement device (MAD) in patients with obstructive sleep apnea.

Table 3. Correlations between changes in apnea-hypopnea index (AHI) and cardiopulmonary coupling (CPC) parameters after use of a mandibular advancement device.

Table 4. Correlations between changes in cardiopulmonary coupling parameters and changes of questionnaire scores after use of a mandibular advancement device.

Conclusion

To our knowledge, this is the first study to evaluate the quality of sleep in patients using a MAD for their OSA based upon CPC analysis. Low frequency coupling decreased as AHI improved while high frequency coupling increased as AHI improved. The CPC parameters showed that the sleep quality was improved by MAD therapy.