EEG spectral power changes before, during and after obstructive sleep apneas

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Abstract

Obstructive Sleep Apnea Syndrome (OSAS) is a very common sleep disorder that is associated with several neurocognitive impairments. The present study aims to assess the power spectral density before, during and after apnea episodes, through the use of autoregressive modeling of the electroencephalographic (EEG) multivariate signal obtained with Polysomnography. The results demonstrate that there is a significant decrease in the EEG power in the delta band during OSAS that does not totally recover immediately after the episode. Since delta waves are linked to learning and plasticity processes, it is hypothesized that decreased delta power during the episode may contribute to the cognitive deterioration in patients with OSAS.

1. Introduction

Obstructive Sleep Apnea Syndrome (OSAS) is a very common sleep disorder affecting 4% of men and 2% of women [7]. It is is characterized by recurrent apneas during sleep, which are caused by the partial or complete collapse of the upper airway, resulting in repetitive hypoxicemic and hypercapnic episodes and interruptions of the normal sleep pattern.

OSAS can contribute to the development of not only respiratory and cardiovascular disorders (hypertension, ischemic heart disease, stroke or cerebrovascular accident) [5] but also neurocognitive impairments. Indeed, OSAS is linked to excessive daytime sleepiness, cognitive dysfunction, fatigue and brain damage.

Neurophysiological assessment through the electroencephalographic (EEG) signal provides an objective method for detecting changes in cortical activity and is accepted as one of the diagnostic procedures for the assessment of cerebral dysfunction. The EEG signal shows patterns of electrical activity, each one characterized by a typical frequency band and amplitude. The normal human EEG shows activity over the range of 1-30 Hz with amplitudes in the range of 20-100 µV [3]. The lowest amplitude waves and highest frequency, 18-30 Hz, are named beta rhythm. Alpha rhythm lies between 8-12 Hz and an amplitude of 50 µV. Larger regular waves of frequency range 4-7 Hz called theta rhythm have been recognized along with a slow wave of less than 4 Hz called the delta rhythm [3].

The current study aims to assess the dynamic changes that occur during OSAS by analyzing the power spectral density of the four EEG frequency bands, in patients with OSAS, using a parametric spectral analysis method, the Yule-Walker autoregressive modeling. For that purpose, we considered several apnea episodes and a period before and after each apnea.

2. Methods

Polysomnographic signals were recorded on a computerized polysomnography system (Somnologica 5.0.1, Embla) during an all night recording of approximately 8 hours duration. EEG electrodes were positioned according to the International 10-20 System and 21 recordings were obtained from the following leads: Fp1, Fp2, Fpz, F3, F4, F7, F8, Fz, C3, C4, Cz, P3, P4, Pz, O1, O2, Oz, T3, T4, T5 and T6, in reference to linked ears (A1 and A2). The EEG signals were acquired at a sampling frequency of 100 Hz. Nasal airflow was also acquired through a nasal cannula and thermistor.

In this study, data from 15 male patients with mild-to-severe OSA were used.

The cessation of the air flow during more than 10 s in NREM-2 sleep stage and a continuous breathing at least 30 seconds before and after apnea, were the criteria for selecting an apneic episode. Each episode was divided into three segments: before (pre), during (dur), and after (post) an apnea event. Pre and post periods have a duration of 30 seconds each, while apneic event have a variable duration between 10 and 20 seconds. Each EEG epoch detected was visually scanned for artifacts and for exclusion of bursts of k-complex and delta activity (subcortical arousals) occurring at the end of the apneic episodes. The resulting dataset included 171 episodes and 513 (171 episodes × 3 periods).
epochs.

Afterwards, the recordings were exported to European Data Format (EDF) files in order to be posteriorly analyzed in the software Matlab 7.5.0, in which all the signal processing was performed.

Each signal sample value was normalized as a function of the signal total power of the corresponding person in order to be possible the comparison across various subjects.

Because there are 21 channels (8 from the frontal, 4 from the temporal and 3 from the central, parietal and occipital regions), the channels of each brain region were "assembled" so that it was possible to analyze each region as a whole. Thus, we obtained 1 signal for each brain region. This assembly was performed according to the following equation:

\[ S_j = \frac{1}{C} \sqrt{\sum_{i=1}^{C} y_{i,j}^2} \]  

where \( j = \{ \text{frontal, central, parietal, occipital, temporal} \} \) is the brain region and \( C \) is the number of channels of the corresponding brain region.

An Yule-Walker autoregressive (AR) model was fitted to the 1D signal obtained in (1) to compute the power spectral density (PSD) in the four referred EEG frequency bands at each period - pre, dur and post. The best model order for each epoch was determined according to the Akaike Information Criterion (AIC).

Powers corresponding to pre, dur and pos for each EEG frequency domain were compared by a two-sample t-test. A p-value < 0.05 was considered statistically significant.

3. Experimental Results

Applying the AR modeling, it was found that mean delta power during an OSA event was significantly lower (p-value < 0.05) than in pre and post. In addition, mean post delta power was significantly lower than pre (Fig.1). There were no significant changes in the other EEG frequency bands (theta, alpha and beta).

4. Conclusions

It was observed that, when the subcortical arousal artifacts are removed, delta power is statistically lower during apnea comparing to pre and pos epochs and, moreover, that after apnea the EEG power cannot immediately recover the values that had before.

Since delta waves are linked to learning and plasticity processes [4], the decrease of delta spectral power during apneic episodes may contribute to the patient’s daytime cognitive dysfunction.

Decreases in delta power preceded arousal and termination of apneic events in both REM and NREM sleep are reported in literature [1, 2, 6]. However, these studies were more interested in the detection of non-visible arousals (subcortical arousals, related to autonomic nervous system), than investigate the PSD changes during OSA events. Indeed, no studies comparing the EEG power spectral density before, during and after apnea were found.

This is a preliminary study. There were no statistical increases in alpha or beta bands after apnea, as it was previously expected, due to the cortical arousals. Thus, further study is required in order to optimize the results.

References