HEART RATE VARIABILITY IN SIESTA POLYSOMNOGRAMS
A Preliminary Study

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Abstract: Nowadays, sleep apnea is a disease with a high prevalence. Its diagnosis requires to admit the patient in a hospital sleep unit and to conduct a polysomnography during the night. For this reason, many efforts have been devoted to alternative techniques to diagnose apnea from other signals, such as ECG or oxygen saturation, easier to obtain outside a hospital. The aim of this work is to investigate if these recordings behave similar to overnight ECGs.This paper presents the results of a small study (only 7 patients) conducted on short naps using heart rate variability (HRV) parameters. The results indicate that the spectral parameters are different for obstructive sleep apnea (OSA) and healthy patients. Relationship with the apnea/hypoapnea index (AHI) was also different. This is a promising starting point for more extensive studies in the future.

1 INTRODUCTION

One of the fields where computerized techniques are becoming increasingly popular is the automated analysis of physiological signals, such as electrocardiograms (ECG) (Roche et al., 2003). Analysis of ECG may provide information related to different respiratory events, such as obstructive sleep apnea (OSA), that is characterized by a cessation of breathing during sleep.

Although precise OSA diagnosis needs a nocturnal polysomnography, there are evidences that heart rate variability (HRV) could offer valuable information in relation with OSA (Penzel et al., 2003). Spectral analysis of HRV can be a suitable tool for the detection of OSA, since it may provide a quantitative analysis and evaluation of the neurovegetative nervous system. Sympathovagal balance can be evaluated with the low frequency (LF) components (ranging from 0.04 to 0.15 Hz) and the parasympathetic tone can be estimated using the high frequency (HF) components (greater than 0.15 Hz). Other indexes can be used, such as LF/HF ratio, which can be used as an indicator of the status of the neurovegetative control system (Gula et al., 2003; Günes et al., 2010). The very low frequency (VLF) band (0.003-0.04 Hz) has also been used by other authors (Park et al., 2008).

Over the last decades, an increasing number of researchers have devoted their efforts to the automatic detection of OSA. In 2000, the Computers in Cardiology conference proposed a competition for classifying potential apneic patients using only the ECG (Moody et al., 2000). Among the proposed systems, one was based on the ratio of the content of two spectral regions between 0.01 to 0.05 Hz, and between 0.005 and 0.01 Hz (Drinnan et al., 2000), while another one used an algorithm based on QRS changes.

Most of the papers cited so far deal with the diagnosis of nocturnal sleep apnea, usually performed by means of polysomnography. However, up to now, no attention has been paid to the apneic events that can occur during the *siesta* period, a short nap in the early afternoon.

Siesta is a Spanish habit that has been proved to contribute to increase productivity, to improve alertness and to reduce risk of accidents (Korman et al., 2007). Furthermore, daytime sleep can lower blood pressure and provide better cardiovascular recovery from psychological stress (Brindle and Conklin, 2011). We think that it can be interesting to study HRV in this type of recordings in order to identify apneic events, and to confirm if they behave in a similar way than overnight polysomnograms.

In this work, we present a preliminary study of HRV indexes on several *siesta* ECG recordings obtained both from apneic and normal subjects. Spectral parameters LF, HF, LF/HF ratio and VLF were calculated and analyzed to determine possible variations during *siesta* time.

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2 MATERIALS AND METHODS

2.1 Database

Seven ECG recordings selected from the polysomnographic database of the Sleep Unit of the University Hospital Complex of Santiago de Compostela (CHUS) were used. This database was obtained using a SOMNOscreen™polysomnograph, built by SOMNOmedics GmbH.

The selected recordings correspond to *siestas* taken by patients suffering different levels of apnea, and by normal, healthy subjects. Average duration of ECG recordings is 158±52 minutes. Subjects' mean age is 61.85±5.78 years, average weight is 96.71±18.08 kg, average body mass index (BMI) is 32.6±4.3 kg/m^2, and mean apnea/hypopnea index (AHI) is 35.6±38.3.

2.2 Methods

Apneic and hypoapneic episodes were detected employing a previously developed algorithm (Otero et al., 2011). Each recording was divided into 5-minute intervals, being each of them labeled as normal (NOR) (suffering from respiratory airflow limitation less than 10% of the interval), borderline (BDL) (suffering from respiratory airflow limitation between 10%-20% of the interval), or apneic (APN) (suffering from respiratory airflow limitation more than 20% of the interval). A total of 69 5-minute episodes were labeled as NOR, 60 were considered to be BDL, and 93 were classified as APN.

Afterwards, beat positions were estimated (Otero et al., 2009) and instantaneous heart rate was calculated. Heart rate signal was automatically filtered and manually checked to remove artifacts or incorrect values. Then, an interpolation using a cubic spline algorithm at 4 Hz. was applied and HRV analysis was performed, employing the RHRV software (Rodríguez-Liñares et al., 2011). This software can be freely downloaded from the R-CRAN repository (`http://cran.r-project.org`).

From this signal, spectral power was estimated applying Short-Time Fourier Transform (STFT) using a Hamming window with mean substraction. Two different frequency analysis were performed: (1) using window length and shifting values of 60 and 2 seconds, which provided values for LF and HF peaks, LF/HF ratio and total power spectrum and (2) using window length and shifting values of 300 and 10 seconds which yielded the very low frequency components (VLF peaks). This data were processed with two different analyses: global and 5-minute interval analysis.

3 RESULTS

3.1 Global Analysis

For each ECG recording, the previously calculated spectral parameters were analyzed. Table 1 shows the results obtained for each recording.

Relationship between spectral parameters and AHI index were also obtained and represented in Figure 1. Besides, both correlation and R^2 coefficients and corresponding p-values were also calculated for the the spectral parameters vs. AHI (see Table 2). It can be observed that HRV and VLF values increase with AHI index. However, this effect cannot be observed for LF and HF parameters, which present approximately constant values with independence of the AHI index. This is consistent with the fact that episode duration for apneic events is around 30 seconds, and this affects heart rate signal in spectral bands corresponding to VLF values.

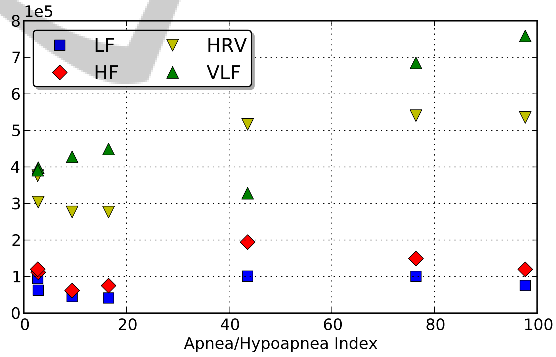

Figure 1: Spectral parameters versus AHI.

One conclusion that can be drawn from Table 2, is that, for VLF and HRV values, the association with the AHI index is stronger than in the rest of spectral parameters. In fact, a percentage of 85% for VLF and 87% for HRV are directly related to the AHI index. Moreover, according to the determination coefficient R^2, 67% of VLF values and 70% of HRV values can be explained in terms of AHI values.

One of the main goals of this work was to test if OSA patients and healthy subjects show different spectral parameters in short nap ECG recordings. To assess this point, polysomnograms were divided into two groups attending to the AHI value: ECGs with AHI$\leq$20 (P20, P89, P91 and P94), and with AHI$>$20 (P17, P24, and P28). Average values of the

Table 1: Spectral parameters for the ECG recordings and mean values for each patient.

Patient	AHI	LF	HF	LF/HF	VLF	HRV
P17	76.4	100596±40781	149277±52534	0.77±0.44	684936±194697	540531±125789
P20	16.5	41386±26277	75209±26898	0.57±0.32	449147±263491	276512±155409
P24	43.6	101119±116014	194149±199706	0.49±0.22	328105±248998	516604±446838
P28	97.7	75712±34125	119715±62307	0.72±0.32	758674±154819	535527±162262
P89	2.8	62620±37349	111660±28171	0.57±0.34	398049±187583	303736±108416
P91	2.7	94788±52122	119965±35293	0.80±0.54	391216±209751	376232±102424
P94	9.4	45262±24613	61541±20971	0.76±0.39	427871±155148	276887±427871
	≤20	58857±41096	88592±36979	0.68±0.42	419218±208201	304463±126673
	>20	92743±88118	162923±153428	0.61±0.32	521760±296559	526474±338824

Table 2: Correlation and R^2 coefficients for the spectral parameters vs. AHI.

	LF	HF	LF/HF	VLF	HRV
Estimate	6.4E-04	3.8E-04	47.24	2.0E-04	2.6E-04
R^2 coefficient	0.02	0.03	-0.17	0.67	0.70
p-value	0.34	0.33	0.75	0.02	0.01
Correlation coefficient	0.42	0.44	0.15	0.85	0.87

spectral parameters were calculated for both groups, and results are presented in the lower part of Table 1.

These results were also evaluated employing a t-test that estimates 95% confidence intervals (95%CIs) and the p-value. Statistically significant differences were found for all spectral values, being the p-value<2.2e-16 in all cases. This indicates the capability of spectral analysis to discriminate between both types of ECG recordings.

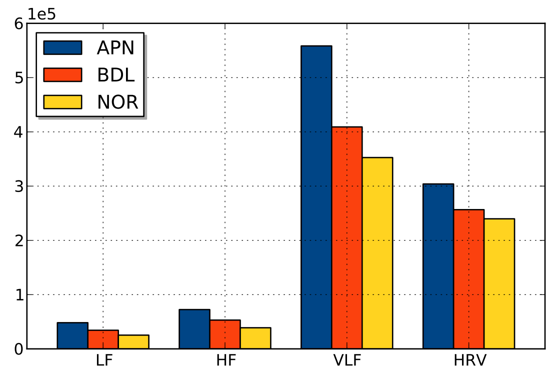

Figure 2: Comparison of episode parameters.

3.2 Five-minute Interval Analysis

As our database contains a low number of ECG recordings, to increase the number of samples, recordings were divided into 5-minute intervals. This allowed to verify if HRV indexes show distinct behaviour in apneic intervals comparing to the baseline. Then, statistical analysis was performed, and the results can be observed in Figure 2 and in Table 3 for each type of episode.

Statistical analysis was performed to assess if there were significant differences between NOR, BDL and APN episodes. Results yielded p-values<0.001 for LF and HF, while VLF only discriminates between normal and apneic episodes, and HRV allows to distinguish between normal intervals and the two other types. No significant differences were found when comparing LF/HF ratio for the three categories of episodes.

4 DISCUSSION

Results suggest a positive correlation between VLF and HRV indexes and AHI, while other indexes show low correlation with AHI. Other works also show correlation between VLF and AHI. Usual duration of apneic episodes is about 20-40 seconds, which corresponds to a range of 0.025-0.05 Hz. Then, a sequence of apneic episodes modulates the heart rate signal, affecting its spectrum, mainly in the VLF band, since frequency range of this band matches the range of typical apneic episodes. As the VLF band usually carries more power than LF and HF bands, global HRV power presents a similar correlation with AHI. Although all HRV indexes show higher values in apneic patients than in healthy subjects (only the LF/HF ratio decreases), conclusions must be drawn with caution due to the scarcity of data. Nevertheless, our experiments gave results similar to other authors' (Park et al., 2008; Roche et al., 2003).

Table 3: Results of the 5-minute interval analysis.

EPISODE LABEL	LF	HF	LF/HF	VLF	HRV
APN	48234±25319	72448±34804	0.69±0.29	558386±342620	303962±71490
BDL	34327±22208	53066±26431	0.65±0.41	409091±319387	256597±97733
NOR	25319±14824	38920±15508	0.63±0.19	352645±177317	239728±82953

We compared HRV indexes in segments with and without apneic episodes using a 5-minutes interval analysis. Results show an increase in all indexes in apneic segments. Borderline segments, corresponding to intervals with few apneic events, give intermediate HRV indexes (bigger than normal intervals and lower than apneic ones). We have not found a similar analysis in the literature, but, if we identify borderline intervals as "mild" apnea intervals, our results could be compared with the ones from (Gula et al., 2003; Park et al., 2008) that show increments in HRV indexes in "severe" apneic patients, compared to "mild" ones.

5 CONCLUSIONS

In this paper we present a preliminary study of apneic patients by means of HRV using polysomnograms acquired during *siesta* time. Results indicate variations in some spectral indexes when apneic events are present, as observed in other overnight studies. This is an interesting result because it could allow to significantly increase the number of patients under observation in a sleep unit.

Although results related to the ECG *siesta* recordings are promising, we must be cautious since a more exhaustive analysis should be performed. However, results presented in this paper suggest the possibility of identifying apneic events in daytime sleep, thus allowing the clinicians to use automated systems to detect apnea in short naps.

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