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Ultradian Rhythms During Day and Night in Normal and COPD Subjects

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Abstract. The analysis of heart rate variability (HRV) is a powerful tool in the study of the autonomic control of the heart. While circadian HRV rhythms have widely been characterized by traditional spectral measures, ultradian oscillations are not commonly investigated. In this study the identification of HRV ultradian rhythms is assigned to a quantitative measure characterizing the fractal-like behavior of the time series: the fractal dimension (FD). In order to assess ultradian regulation in Chronic Obstructive Pulmonary Disease (COPD) 24-h Holter ECG recordings of 52 COPD and 10 normal (healthy) subjects were analyzed. The FD was calculated by Higuchi's algorithm both during daytime and nighttime to highlight possible wake-sleep states differences. All subjects showed a similar common rhythm (0.06mHz) that persists with generally higher amplitude during night-time. A further rhythm becomes predominant in normal subjects in the day-to-night transition (0.15mHz), probably under the influence of the REM/non-REM ultradian sleep cycle. A very large difference between night and day amplitudes of this rhythm and of the next one (at about 0.22mHz) characterize the HRV fractal dimension of the Normal in respect of COPD. In conclusion, the FD could be used as a marker of ultradian cardiac autonomic regulation providing new insights into autonomic physiology of normal and COPD patients.

Keywords. HRV, Fractal dimension, Ultradian rhythms, COPD

Introduction

Heart rate variability (HRV) is a well-recognized tool in the autonomic system assessment [1]. HRV is characterized by a broad time structure including both the prominent circadian rhythm but also ultradian cycles (UO) repeated throughout a 24h-period as well as infradian cycles (IO) longer than a day. While circadian rhythm in the HRV has widely been characterized by traditional spectral measures [2-5], UO have been studied less extensively and no agreement has been reached on their periodicity [6-10] This study was therefore designed to examine the UO of HRV with particular attention to the day-to-night possible variations. Under the assumption that fluctuations in the RR series may highlight properties from complex dynamic systems, the rhythmometric analysis was conducted on the basis of non-linear parameterization. The HRV index chosen to be analyzed is the fractal dimension (FD), characterizing the fractal-like behavior of the time series. The temporal evolution of the FD throughout the 24 hours was examined, by power spectral analysis, in the day-time and in the

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night-time, separately. This approach was applied to analyze HRV of both normal subjects and patients affected by chronic obstructive pulmonary disease (COPD).

1. Methods

Sixty-two HRV series extracted from 24-h Holter recordings of 10 normal subjects and 52 COPD patients were analyzed. The fractal analysis was performed according to Higuchi's algorithm [11] and the fractal dimension (FD) values were computed over sliding segments of 5 minutes. The calculated FD series were low-pass filtered and detrended in order to remove the mean value and the possible linear trend. The power spectrum density (PSD) of FD was then estimated, by periodogram method, for the day-time (15.00-20.00) and the night-time (23.30-5.30), separately. The spectra were finally averaged on the subjects belonging to each population. The frequencies and the corresponding amplitudes of the first three PSD peaks were considered to evaluate possible differences between day-time and night-time values as well as between the two groups during day and night-time. The statistical analysis was performed by using paired (differences within the same group) or independent (comparison between groups) non parametric Wilcoxon test.

2. Results

Figure 1 shows the frequencies and amplitudes mean values corresponding to the first three peaks in the PSD of FD averaged on the subjects of the two groups during night and day-time. F1 value significantly ($p<0.008$) decreases from day to night in Normal while it remains constant in COPD patients. F2 and F3 values significantly decrease from day to night both in Normal ($p<0.002$) and in COPD patients ($p<0.04$). The small differences between corresponding Fi (i=1,2,3) frequencies in Normal and COPD patients are not significant. Thus the main rhythms are similar in the two groups even if Normal presents larger differences between day and night time than BCPO subjects. The amplitudes show a very large increment between day and night in Normal with significant differences for A2 ($p<0.02$) and A3 ($p<0.002$) amplitudes while in COPD patients smaller increments are present, significantly only for A3 ($p<0.01$). However, in Normal during night the amplitude at first increases and then decreases with the frequency while, in all the other three cases, the amplitude decreases as the frequency increases (Fig.1). The amplitudes show significant differences between Normal and COPD patients at all the three frequencies during the day ($p<0.04$) and at F2 and F3 during the night ($p<0.02$). Moreover, COPD subjects present greater values during the day while Normal have dominant values during the night.

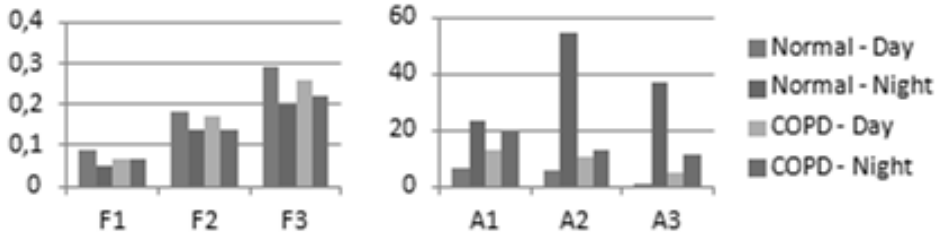

Figure 1. Frequencies (F1, F2 and F3) and amplitudes (A1, A2 and A3) mean values corresponding to the first three peaks in the PSD of FD averaged on the subjects of the two groups during night and day-time

3. Discussion

Results showed that day-time HRV of normal subjects is characterized by three main ultradian rhythms of quite similar amplitude at 0.09mHz, 0.18mHz and 0.3mHz that persist, at slightly lower frequencies (0.05mHz, 0.14mHz and 0.2mHz) during night-time. However, in the day-to-night transition, the second rhythm became predominant. The large increase in power could be explained, as suggested by Ichimaru et al. [10] and Yamazaki et al. [6], by the influence of the REM/non-REM ultradian sleep cycle. The HRV of all patients revealed some differences (especially in the amplitudes) in the rhythmometric structure as compared with that of normal subjects.

4. Conclusions

The present study aimed at the identification of HRV ultradian rhythms, in the day-time and in the night-time, in different COPD patients in respect of Normal subjects. The analysis was conducted on the basis of non-linear theory by assessing the FD temporal evolution of the HRV throughout the 24 hours. The results suggest that three main ultradian rhythms characterize the autonomic control of the heart, probably influenced in the night-time by the REM/non-REM ultradian sleep cycle. Since differences were observed between normal subjects and COPD patients, it is reasonable to assume that in the near future HRV ultradian rhythms may have prognostic value in clinical practice. However, more detailed investigations are required.

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