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ADRENALINE EFFECT ON THE ACTIVITY OF CARDIAC CELLS

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Abstract. The increased content of adrenaline in emotionally stressed people is known as a major source of heart beat acceleration. Using the electrocardiographic recordings (ECG) the influence of the adrenaline on the electric activity of heart muscle cells has been indirectly investigated. Physiologically normal and emotional loaded voluntary human subjects have been studied. Computationally tests based on the Hurst exponent and the capacity dimension have been used to get numerical data able to make the difference between the two physiological situations. While Hurts exponent led to similar values in both situations the capacity dimension has provided higher values for correspondingly higher adrenaline content indicating higher complexity in the electric activity of emotional subjects heart

INTRODUCTION

Among the mostly often invoked neurotransmitters, the adrenaline is known especially due to its deep involvement in the daily stress situations of the human modern society. The study of adrenaline metabolism is based both on direct and indirect investigation methods: molecular, biochemical and genetic methods on a hand – electrophysiological, clinical and behavioral methods on the other hand. In the last decades the computational methods became an appreciated alternative to the experimental data interpretation and even for prediction of future behavior. Since one of the first application of nonlinear methods to the analysis of emotional stress effect on cardiac muscle cell physiology was reported in the ’90 years (Reidbord & Redington, 1992), many other computational studies have been developed since our days. Computational analysis of the ECG signal are related, for instance, to the next aspects:

-the evidence of the changes in heart rate variability during induction of general anesthesia (Sleight, 1999, Pomfrett, 1999);
- the study of the respiratory influences on non-linear dynamics of heart rate variability (Fortrat et al., 1997) ;
-the theoretical investigation of turbulence (Lin et al., 2001) and non-stationarity in human heart (Bernaola-Galvan et al., 2001);
- the study of heart rate variability in different generations (Yoshikawa and Yasuda, 2003);
-the study of cardiac arythmia (Lass, 2002).
- the application of wavelet analysis of heartbeat intervals discriminates healthy patients from cardiac ones (Thurner et al., 1998);

In this paper we present the results obtained in the analysis of two series of electrocardiographic (ECG) signals recorded for health subjects in different emotional situations: relaxed and respectively stress loaded (when the adrenaline is supposed to be delivered in higher amount in the body.

MATERIALS AND METHODS

ECG Data series. Two lots of ten ECG data series each have been recorded in digital version using a portable electrocardiograph convenient for laboratory investigations (10) (Creanga et al., 2000) (signal sampling was done with a frequency of 5000 Hz). Relaxed physiological state was assigned to young healthy students invited as voluntary for the electrocardiographic recording while high adrenaline level was supposed to be generated by emotional stress induced further in similarly subjects by submitted them to a non-announced test of evaluation of their activity. The linear and non linear computational tests have been applied on series of 10.000 data each). Student t-test, pair, two tailed was applied using Ms Excell soft to compare normal and stress loaded cases.

Computational algorithms. (i) The Hurst Exponent (11). One common type of time series arises from a random “walk” within the data series, sometimes called Brownian motion. In such a case, the value of X (t) (the measured temporal parameter in the studied system) on average moves away from its initial position by an amount proportional to the square root of time (the power equal to 1/2), and we say the Hurst exponent is 0.5. The root-mean-square displacement (DX(t)) is plotted here versus time, using each point in the time series as an initial condition. The slope of this curve is the Hurst exponent. Exponents greater than 0.5 indicate persistence (past trends persist into the future), whereas exponents less than 0.5 indicate antipersistence (past trends tend to reverse in the future). Thus, when the analyzed data present an appearance of randomness one might integrate it and search if the exponent is close to 0.5, which would imply that it is random and uncorrelated (higher complexity or chaotic trend in the studied system). Exponents higher than 0.5 are indicating correlated data (higher linearity in the studied system).

(ii) **The capacity Dimension.** Similar to the Hausdorff dimension (11), the capacity dimension is calculated by successively dividing the phase space (a hyperspace which can be recovered from an unique measured temporal parameter) with embedding dimension D (the embedding dimension being a measure of the observation scale used to study the system) into equal hypercubes and plotting the log of the fraction of hypercubes that are occupied with data points versus the log of the normalized linear dimension of the hypercubes. The average slope of the line for the two middle segments is taken as the capacity dimension. As the embedding dimension is increased, the capacity dimension should increase but eventually saturate at the correct value. Many data points are required to get an accurate estimate of the capacity dimension if the dimension is high. A dimension greater than about five implies essentially random data while smaller values are indicating the presence of high complexity degree (chaotic trends). In the following we present the results of the calculation of the Hurst exponent and of the capacity dimension in the two lots (of ten data series each) of ECG recordings.

RESULTS AND DISSCUSIONS

In figure 1 a, b the raw data recorded in normal and respectively nervous subjects are given. Differences at the level of the ECG amplitudes and durations can be seen in the case of emotional stressed subject, probably due, mainly, to the muscle cell increased excitability under the influence of higher level of adrenaline (the time duration between two consecutive ECG signals appeared significantly shorter for stressed subjects). In previous published article (Creanga, 2004) it was shown that the power spectrum of the ECG signal exhibits significant flat regions for medium and high frequencies for both normal and emotionally stressed subjects. This could suggest either randomic (noisy) or chaotic trend overlapped onto the quasi-period dominant dynamics (the linear behavioral trend). The Hurst exponent is able to show if the flat power spectrum corresponding to the analyzed signal is related to a randomic or to a chaotic system. In the present study the application of the Hurst exponent algorithm revealed in both situations significant high values (over 0.99) excluding the randomic fluctuation presumption (fig. 2 a, b). So, the deterministic (or liner) trend (quasi-periodic component of the ECG signal) is strongly dominating the heart dynamics in both analyzed situations. In figure 3 a, b the capacity dimension is represented for the raw data series. As mentioned above, the result of this computational test is able to provide information upon the fractal dimension of the system attractor. As reported in other paper (Neacsu et al., 2005, General Physiology and Biophysics, Bratislava, in press) the ECG data series recorded in adrenaline loaded subjects are characterized by rather similar attractors (the totality of the points representing the possible equilibrium states in the system evolution) with non-integer correlation dimension values (the correlation dimension being an alternate way of expressing the fractal dimension of the system attractor). No saturation tendency was noticed in the two groups of subjects suggesting the significant fluctuation role (either from the recording noise or from intrinsic causes).

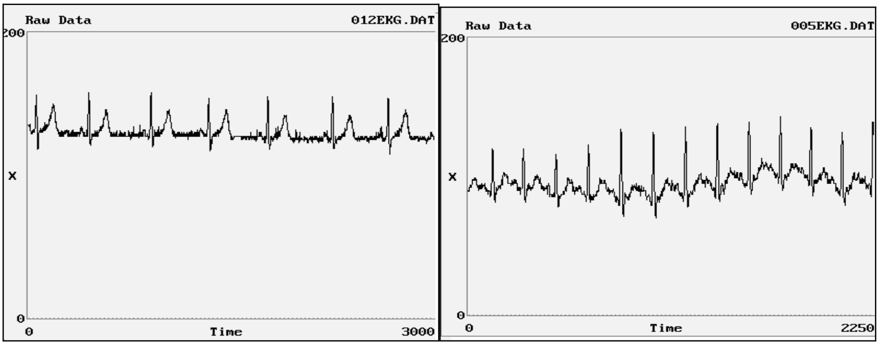

Figure 1 a-b. Normal ECG (a-left) and adrenaline loaded ECG (b-right)

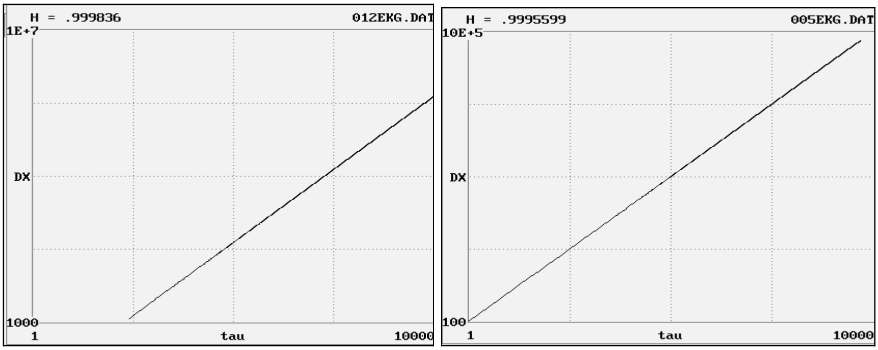

Figure 2 a-b. Hurst exponent versus time in normal (a-left) and adrenaline loaded subjects (b-right)

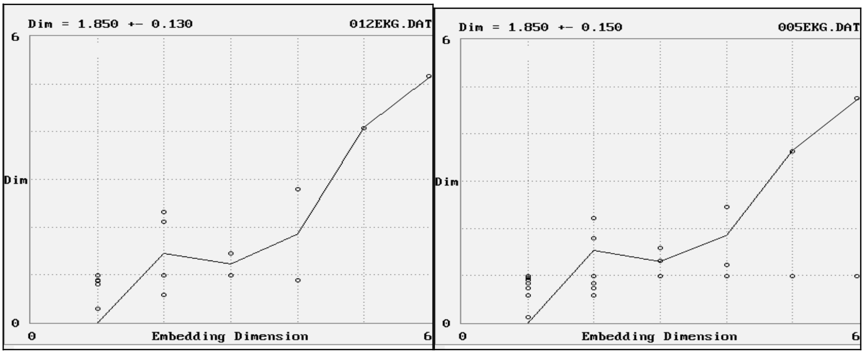

Figure 3 a-b. The capacity dimension versus embedding dimension in normal (a-left) and increased adrenaline subject (b-right)

Considering the limited precision of the computational test, the smoothed data have been also analyzed (every point is replaced by the averaged value between the point and its two closer neighbors). In figure 4 a, b the results obtained for ECG smoothed data series are represented. The differences between the two discussed situations are obvious now. The capacity dimension tends to saturate to higher value (1.652 in comparison to 1.112) in the case of higher adrenaline level (fig. 4 b) suggesting increased complexity degree in this group of subjects.

Averaged values for every ten individual values obtained in the physiological normal group and the high adrenaline one presented standard deviation of 8.56%. The application of the t-test revealed significant differences between the capacity dimension values of the tow lots of subjects accordingly to the significance level of 0.05. It seems that numerical smoothing was able to reveal the higher weight of the chaotic component within the adrenaline loaded subjects.

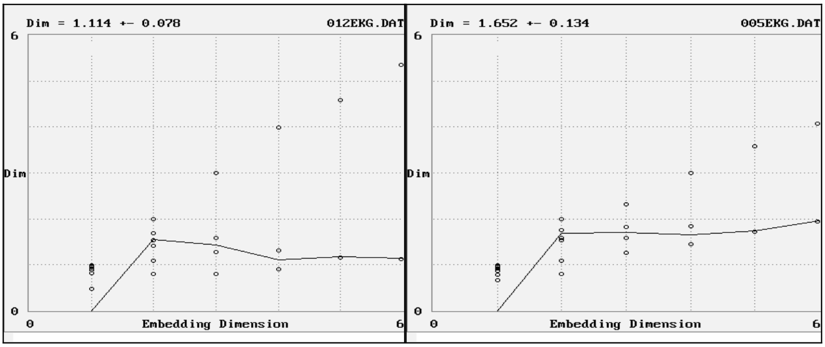

Figure 4 a-b. The capacity dimension versus embedding dimension for the smoothed data corresponding to normal (a-left) and adrenaline loaded subjects (b-right)

CONCLUSIONS

The stress hormone – the adrenaline, that is supposed to be significantly increased in the emotionally stressed subject group seems to be able to induce significant changes in the ECG data series. The capacity dimension was suitable for the evidence of the differences between physiological normal and stressed people.

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