EVALUATION OF HEART RATE VARIABILITY USING RECURRENCE ANALYSIS

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INTRODUCTION

There is an increasing importance of nonlinear analysis of biological data in the last few years. We can describe selected processes generated in living organism much more effectively using specific methods of nonlinear analysis. Recurrence analysis - the subject of this study - is one of these techniques.

GOAL

The main goal of our study was to verify the possibilities of recurrence analysis in neuroscience.

METHODS

Recurrence plots - the basic instrument of recurrence analysis allow visualization of phase space trajectories using two-dimensional graph. During recurrence analysis the pair test is computed. For N states, we compute N2 tests. If the distance between the two states i and j in trajectory less than the threshold ε, the value of the element in the recurrence matrix R is one, otherwise this value will be zero [1, 2].

RP can be mathematically expressed as

$$R_{i,j} = \Theta\left(\varepsilon_i - \left\| x_i - x_j \right\|\right), \qquad x_i \in R^m, \quad i, j = 1 \ldots N,$$

where N is the number of considered states x_i, ε_i is a threshold distance, $\|\cdot\|$ is a norm, $\Theta(\cdot)$ is the Heaviside function.

The structures created in RP represent the basis for so-called recurrence quantification analysis (RQA). It is a set of parameters introduced by Zbilut and Webber [2] for the possibility of quantitative evaluations of RP.

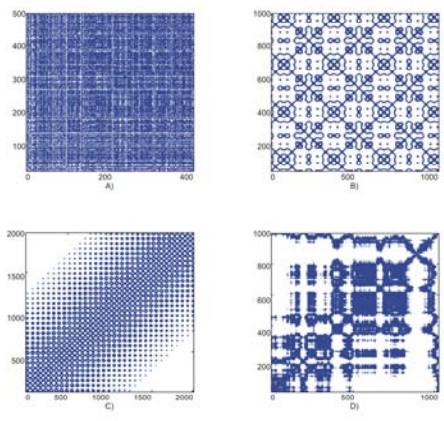

Figure 1: Characteristic typology of recurrence plots: (A) homogeneous (uniformly distributed noise), (B) periodic (harmonic oscillations), (C) drift (system with linearly increasing term) and (D) disrupted (Brownian motion).

RESULTS

We found significantly higher percentage of recurrent points from RQA measurement in patient with CMT and FPV compared with control group. RQA measurement based on diagonal lines showed significantly higher percentage of points forming diagonal lines (the value of DET parameter - determinism), in group with CRPS and PRE-COLL compared on the control group.

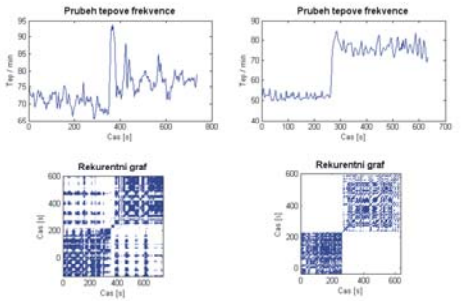

Figure 2: Comparison of heart rate graph and recurrent plot, on left patient with CMT, on right healthy non-trained proband during orthostatic test.

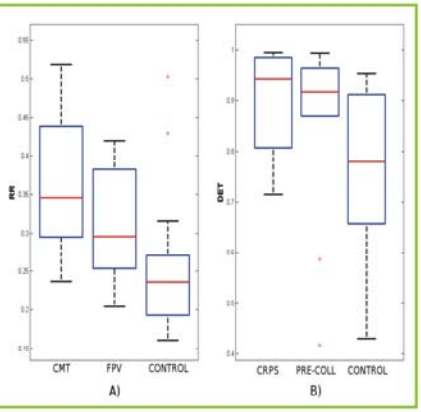

Figure 3: A) Box plot illustrating the comparison of percentage of recurrence points (RR) between control group and FPV (P=0.025) and between control group and CMT (P=0.005). B) Box plot illustrating the comparison of percentage of determinism (DET) between control group and PRE-COLL (P=0.005) and between control group and CRPS (P=0.1). Box plot shows interquartile range of values with central line indicates median.

CONCLUSION

We have verified the possibility of using recurrence analysis for the evaluation of heart rate variability. The RQA parameters can be used together with commonly used parameters of HRV to evaluate the heart rate variability in neuroscience. The main RQA parameters suitable for the evaluation of HRV are recurrence rate (RR), determinism (DET), entropy (ENTR) and longest vertical line (MAXV).

REFERENCES

[1] MARWAN, Norbert. Encounters with neighbours: current developments of concepts based on recurrence plots and their applications. Potsdam, 2003. 331 s. Dizertační práce. University of Potsdam. Dostupné z WWW: <http://www.recurrence-plot.tk/furtherreading.php>. ISBN 3000123474,9783000123474.

[2] SCHINKEL, Stefan; DIMIGEN, Olaf; MARWAN, Norbert. Selection of recurrence threshold for sigal detection. European Physical Journal : Special Topics. 2008, 164, s. 45-53.