Recurrence Analysis in Patients with Vasovagal Syncopes

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Abstract. *This paper presents the possibility of using recurrence analysis for the vasovagal syncopes detection. The recurrent analysis is very promising nonlinear technique which is able to analyse system's dynamics. The main part of the work focuses on evaluation of heart rate variability using recurrence analysis in group of patients with vasovagal syncope and control group. The result of the work is the set of measures derived from recurrence analysis suitable for vasovagal syncope detection.*

Keywords: Recurrence Analysis, Recurrence Plot, Heart Rate Variability, Vasovagal Syncope

1. Introduction

Vasovagal syncopes are one of the causes for symptomatic orthostatic hypotension, associated with increased tone of parasympathetic part of autonomic nervous system, leading to sudden drop of blood pressure and heart rate, resulting in occasional fainting and black-outs, usually after standing-up. Blood pressure and heart rate drop can be diagnosed by head up tilt testing and heart rate as well as blood pressure variability analysis. Human heart rate is strongly influenced by autonomic nervous system, which is a typical example of non-linear system [1, 2]. Recent studies shows that recurrence analysis is very promising nonlinear technique used in cardiology and neurology, which is capable to describe discrete abnormalities in heart rate regulation [2, 3, 4, 5].

Recurrence plot (RP) is basic tool of recurrence analysis and it is used for graphical representation of recurrences in dynamical system [5, 6]. The great advantage of RP is visualization of multidimensional phase space in two-dimensional graph (see Fig. 1). The starting point of recurrence analysis is phase space reconstruction. Phase space represents all possible states of system. One of the most commonly used methods for phase space reconstruction is Taken's theorem [7]. In Taken's method there are two input parameters, embedding dimension and time delay. The optimal set of these parameters is important for the space reconstruction that fully describes system dynamics [6]. After phase space reconstruction the pair test of all states is done. For distance between two states in phase space trajectory smaller than given threshold, recurrent point in RP arises [7]. There are several methods for threshold distance setup. However, authors are not uniform about it so far [8, 9]. RP are quantified by recurrence quantification analysis (RQA). This RQA is a set of measures based on diagonal and vertical structures [5, 6].

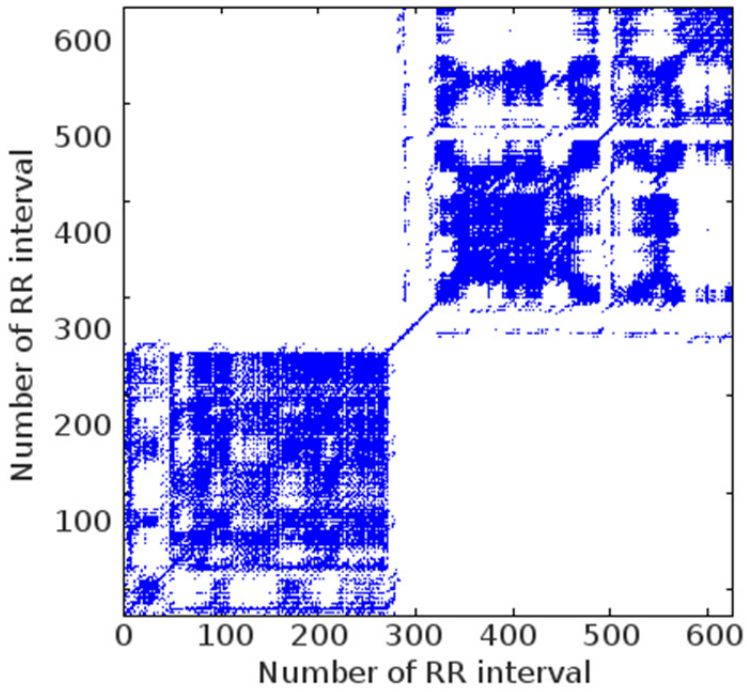

Fig. 1. An example of recurrence plot (input signal: R-R intervals measured during orthostatic test).

2. Subject and Methods

In this study 26 subjects divided into two groups participated. The first group (Syncope) consisted of 13 patients with vasovagal syncope. The control group consisted of 11 women and 2 men aged 15 to 28 years (mean age 21 and median 21 years). The second group (Control) consisted of 13 healthy subjects. There were 6 women and 7 men in control group aged 20 to 33 years (mean age 24 and median 24 years). All subjects gave their informed consent to examination. All subjects were examined from 8 to 12 am in a quiet room. We use R-R intervals from orthostatic test as an input signal. Orthostatic test has two phases (resting in supine position and standing position). Subjects were resting in supine position for 5 minutes then they were asked to stand up slowly and recording was continued in standing position for another 5 minutes. Schwarzer FAN Study (FAN®, Schwarzer, Germany) was used for heart rate monitoring and blood pressure measuring.

We use a script created in Matlab for the recurrence analysis. The lengths of R-R intervals are used as an input signal. For each recording we determine the optimal embedding dimension using false nearest neighbor method [10] and optimal time delay as the first minimum of the mutual information function [11]. For threshold distance we use method with fixed percentage of recurrence points %RR = 5% [2, 5].

The calculated measures of RQA were statistically evaluated by two-sample t-test and chosen measures were processed in a form of boxplot graphs. Values with $p < 0.05$ were considered statistically significant.

3. Results

We found significant differences between several RQA measures in patients with vasovagal syncope compared with control group. There are significantly higher percentage of points forming diagonal lines (Determinism – DET) and length of the longest diagonal line (LMAX). Higher DET means that system returns to the previous states more often and this

measure is associated with system predictability. RQA measurement also shows significant differences in the Divergence (DIV) which is related with Kolmogorov-Sinai entropy [6], and Shannon entropy (ENTR). Our results in boxplot graphs are shown in Fig. 2. Boxplot shows maximum, minimum, median, first and third quartile. Cross points are outliers.

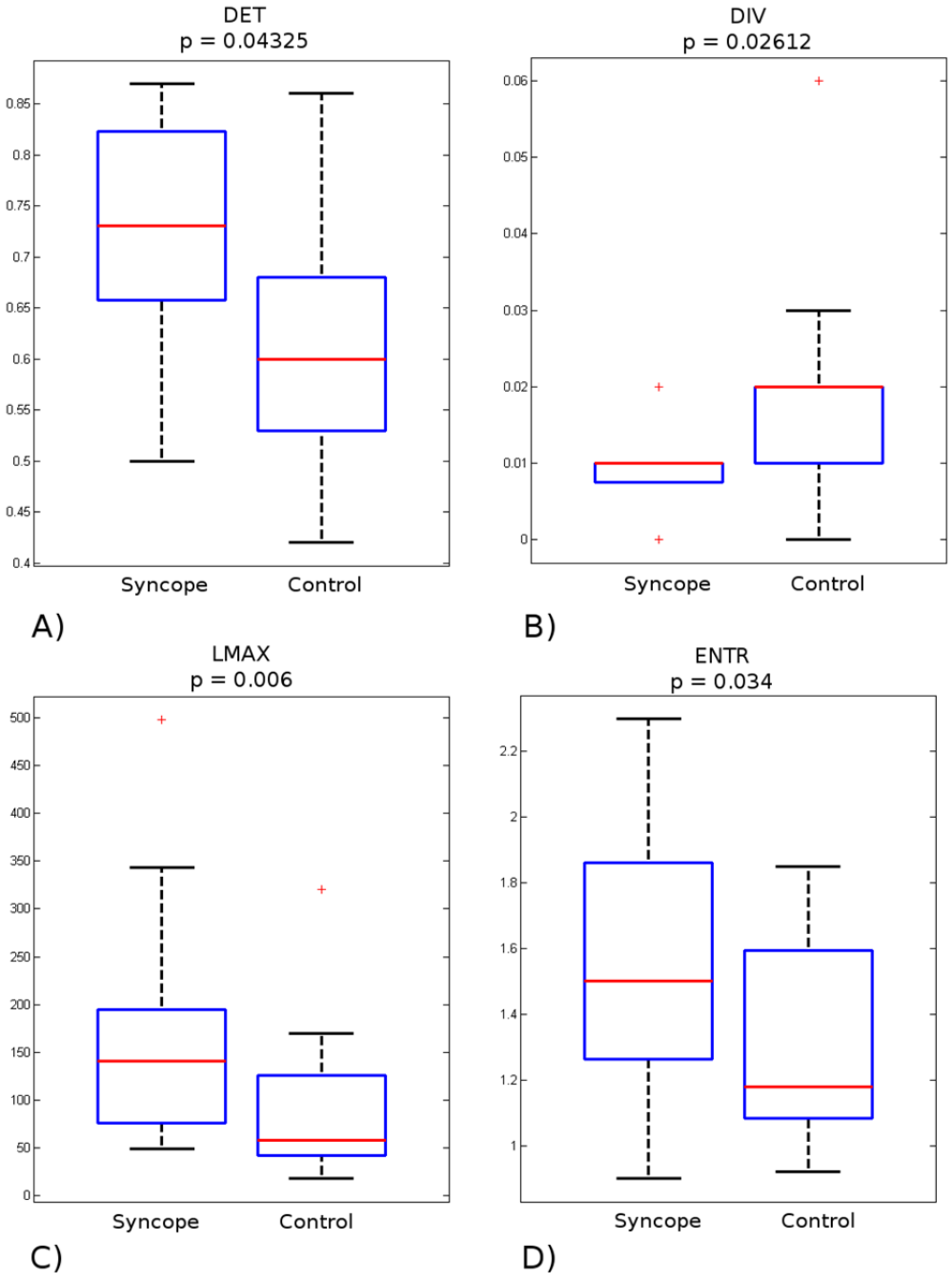

Fig. 2. Boxplots illustrating the comparison between patients with syncope and control group. A) Determinism (p = 0.04225). B) Divergence (p = 0.02612). C) The length of the longest diagonal line (p = 0.006). D) The Shannon entropy (p = 0.034).

4. Discussion

The major findings of our study are significant differences in measures derived from recurrence analysis in patients with vasovagal syncope. The lower heart rate variability is indicated by the higher "percentage of points forming diagonal lines" (DET) and the higher "length of the longest diagonal line" (LMAX) in patients group. These changes in HRV

revealed by recurrence analysis may indicate pathological conditions. The main limitation of our study is small number of subjects in the groups and no gender-matched control group. Therefore, future studies on this field are needed.

5. Conclusions

We discovered the reduced complexity of heart rate control in young patients with vasovagal syncope using the recurrence analysis. The main RQA measures suitable for the evaluation of HRV in patients with vasovagal syncope are determinism (DET), divergence (DIV), length of the longest diagonal line (LMAX) and Shannon entropy (ENTR).

Acknowledgements

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