Assessment the Dynamics of ECG Parameters Interactions During Invasive Procedures

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Introduction. The signals dynamic interactions characterizing individual systems are very significant to the human body, as complex adaptive system, functions' analysis. Parameters identification, method sensitivity analysis and understanding the physiological significance of final results still remains an actual problem [1, 2]. The full potential of fractal mathematics and chaos theory remain to be realized, and await further development, although these concepts have already provided revolutionary insights into the nature of the living things [3]. The dynamical fluctuations of the signals obtained in complex biological systems provide a unique opportunity to analyze the free running behavior of the integrative systems. As linear methodologies fail to provide significant information in conditions of extremely reduced variability (e.g. myocardial infarction) and in presence of rapid and transient changes the development of new nonlinear approaches seems to provide a new perspective and gives quite important results [4].

The aim of presented work is evaluation of the impact to cardiovascular system function of two invasive procedures, i.e. instrumental recanalization of heart vessels and radio frequency ablation of heart rhythm disorders. The method designed for extracting information in time series generated by complex living systems and based on the matrix theory with considering the inter-parameter relationships obtained during monitoring of ECG [5] is used.

Material and methods. For the investigation of interaction between two objects, two synchronous time series $(x_n; n = 0,1,2,\ldots)$ and $(y_n; n = 0,1,2,\ldots)$, representing the exploratory object are formed in which x_n and y_n are real numbers representing the recorded ECG parameters. When elements of the series are determined variables, information about the object of investigation is described using special mathematical equations [6].

The matrix time series are constructed as follows:

$$A_n := \begin{bmatrix} a_n & b_n \\ c_n & d_n \end{bmatrix}, \qquad (1)$$

where $a_n := x_n$, $b_n := x_{n-1} - y_{n-1}$, $c_n := x_{n+1} - y_{n+1}$, $d_n := y_n$. Other mathematical relationships can be used to form these series. Before evaluation of the characteristics describing cohesion of ECG parameters some numerical parameters of second order matrices A_n must be introduced: $\mathrm{Tr}A_n := a_n + d_n$

(trace of matrix A_n), $\text{dfr} A_n := a_n - d_n$ (difference), $\text{cdp} A_n := b_n \cdot c_n$ (co-diagonal product). From these initial parameters the following characteristic, i.e., discriminant (dsk) which has more applicative sense is calculated:

$$\text{dsk} A_n = (\text{dfr} A_n)^2 + 4\,\text{cdp} A_n \text{ (discriminant).} \tag{2}$$

The investigated contingent consisted of three groups of persons - patients of Cardiologic Clinic at LUHS Hospital: group I contains 53pts with anterior myocardial infarction (AMI), group II – 40 pts with inferior myocardial infarction (IMI), patients of I and II group underwent the coronary re-canalization procedures; group III contains 21 pts with heart rhythm disorders which underwent the radio frequency ablation (RFA) procedure. The ECG parameters in 12 leads of continuous monitoring were recorded by using ECG analysis system developed in the Institute of Cardiology at LUHS. Three ECG parameters, i.e., lengths of RR, JT intervals and QRS complex were analyzed. For group I pts (AMI) these parameters were taken from lead V3, for group II pts (IMI) - from lead aVF and for group III pts (RFA) - from lead II. From obtained RR, JT and DQRS the following discriminants (Dsk) before and after invasive procedure are calculated: Dsk(RR; JT), Dsk(JT; DQRS) and Dsk(RR;DQRS). Besides the parameter S(Sensibility) S1(RR; Dsk(RR; JT)), S2(RR; Dsk(JT; DQRS)) and S3(RR; Dsk(RR;DQRS)) reflecting cohesion between regulatory parameter RR and discriminants and measured by angle between regression line and discrminant axes is also calculated (see Fig. 1).

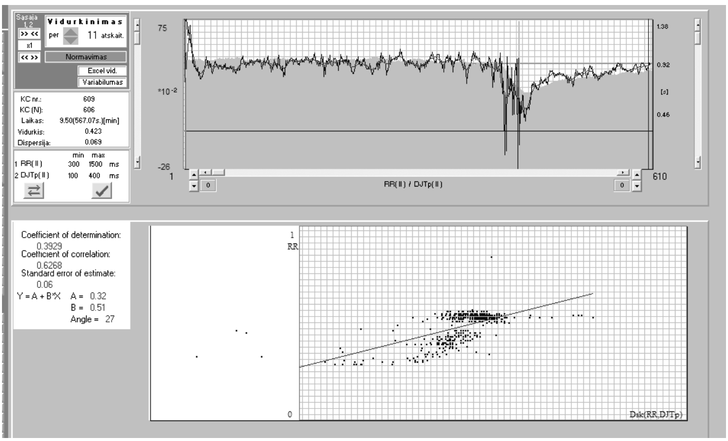

Fig. 1. RR intervalogram (grey area) and Dsk(RR; JT) diagram (upper part);
Calculation the parameter of sensibility S(RR; Dsk(RR; JT)) (under part).

Results and discussion. MI is qualified as a big stress for human organism, and ample changes of ECG parameters are observed during MI. The heart rate and metabolic features usually are changed but still is not clear in which fractal level those changes are mostly prominent. Such information could be obtained from parameters interconnections when matrix analysis is used.

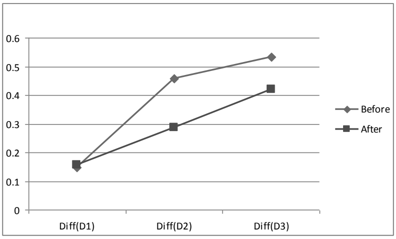

Fig. 2. Differences of Dsk for pts with Anterior MI

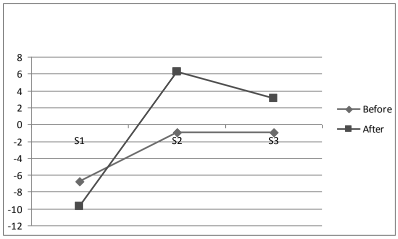

Fig. 3. Changes of sensibility for pts with Anterior MI

In Fig.2 there are presented Dsk in three levels: Dsk in first level - between RR interval (regulatory system parameter) and JT interval (reflecting metabolic features in heart), and its changes are minimal; Dsk in second level shows interconnection between different regulatory system fractal (RR interval and duration of QRS complex), and here the biggest changes are observed; the same could be stated for changes in third level (JT interval and QRS duration). The changes observed in Fig.3 repeat the changes in Fig.2, and so we could make decision that in case of Anterior MI the main changes appear in regulatory interactions between organism and heart levels but only small changes take part in regulatory and heart metabolic interactions (D1 in Fig.2 and S1in Fig.3).

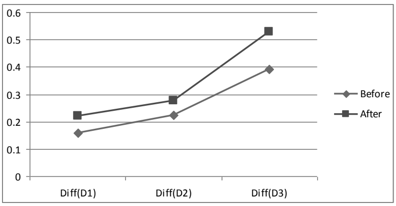

Fig. 4. Differences of Dsk for pts with Inferior MI

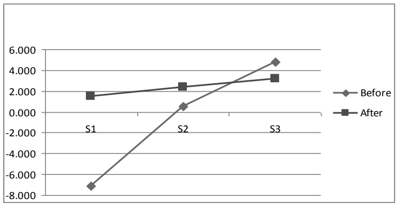

Fig. 5. Changes of sensibility for pts with Inferior MI

Quite different reaction during invasive procedure we can find in case of Inferior MI. In Dsk values we observe only very small changes (Fig.4) but

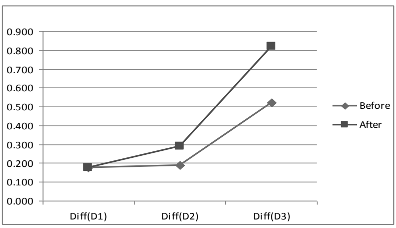

Fig. 6. Differences of DSK for RFA pts

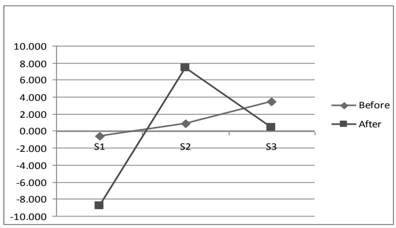

Fig. 7. Changes of sensibility for RFA pts

sensibility to procedure has the biggest change in regulatory – metabolic interactions (Fig.5, S1 point). In RFA procedure we observe another human organism reaction style, different from reaction to procedures in case of MI. Here we can find suspected reaction mainly expressed in regulatory levels (Fig.7, S1 and S2 points).

Conclusions. Every pathology in human organism has its own "face", i.e., it changes the interactions between different organs and creates its own attractor. Myocardial infarction of different localization has different influence to heart – organism interactions. The matrix analysis allows evaluating the changes of interactions in human organism during invasive procedures.

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