Stability analysis of RR and QT variability for cosmonauts data

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Abstract – **Stability analysis of cardiovascular oscillations together with nonlinear analysis gives important and complements information about their autonomic regulations. New nonlinear tools like M-indexes gives possibility to analyze stability of the most pure dynamic process that is observed with the help of RR and QT intervals variability.**

Keywords — **RR variability, QT variability, stability analysis, M-indexes**

I. Introduction

Space flight has an important impact on almost all of the human body's systems, particularly the cardiovascular system [1]. Variability of cardiovascular oscillations has become a universal tool to study the neural control of the heart and include a variety of linear, non-linear, periodical and non-periodical oscillation patterns that are present in heart rate fluctuations [2]. The nonlinear methods represent promising tools for variability assessment and should be completed by stability analysis.

There are different approaches to stability analysis for cardiovascular behaviour. They can be understood in qualitative sense as: cardiovascular reactivity in psychophysiology, e.g. blood pressure and heart rate reactions [3]; spontaneous oscillations in systemic arterial pressure as the result of instability inducted by baroreflex [4]; as electrical stability, e.g. absence of its opposite in clinical interpretation [5]. Very few papers can suggest time series stability analysis quantitatively because of problem complexity. Mostly they are based on linear methods of investigations [6] or interpret stability in structural sense [7].

The current study presents new stability analysis tool based on M-index measure of nonlinearity and nonstationarity. Applied stability investigation was made for RR and QT variability of cosmonauts before and after space flight.

II. Materials and Methods

Subjects: 4 cosmonauts; 20 days before space flight (4 records) and on the 1st (3 records), 4th (3 records) and 5th (1 record), 7th (1 record) and 9th (3 records) days after space flight.

Signal acquisition: 2 minutes of 2 channels high resolution (1 kHz) digital ECG recording was made by Prof. A.Aubert group. Automatic RR and QT detection and verification was made by Prof. A.Martynenko group.

Stability analysis of RR and QT variability: We use the term stability in Lyapunov sense as applied to short interval of time series observation. Naturally we can only make a conclusion that during time of observation data are stable, unstable or neutral. It is impossible in classical sense to make a decision about infinite or asymptotical behaviour of time series.

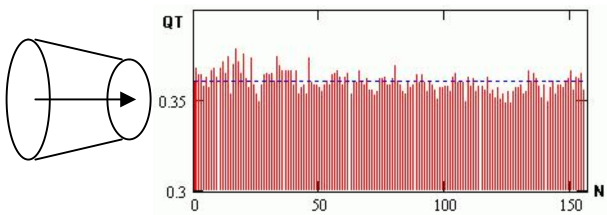

Fig. 1 Stable pattern behaviour and example of stable QT intervals (D2 data)

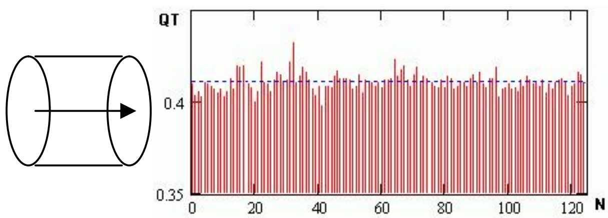

Fig. 2 Neutral pattern behaviour and example of neutral QT intervals (D4 data)

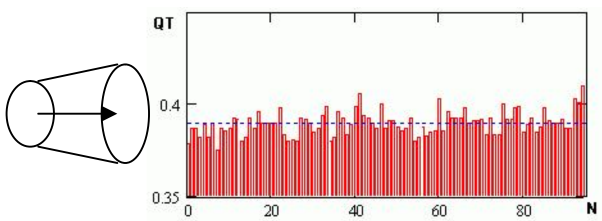

Fig. 3 Unstable pattern behaviour and example of unstable QT intervals (B3 data)

We define: *Stable* behaviour if on the regular basis during the time series observation their phase space is shrinking; *Neutral* behaviour if on the regular basis during the time series observation their phase space doesn't change in the mean; *Unstable* behaviour if on the regular basis during the time series observation their phase space is expanding.

The patterns and examples of QT intervals behaviour are shown in Figure 1-3.

All calculations we make are based on M-index that is a complex measure of nonlinearity and nonstationarity of time series in time symmetric (M_0) and time asymmetric (M_1) phase space [8].

III. Results

The result of stability calculations for RR and QT intervals variability of cosmonauts data are shown in Figure 4-7 ("-" or green area – stable; "+" or red – unstable).

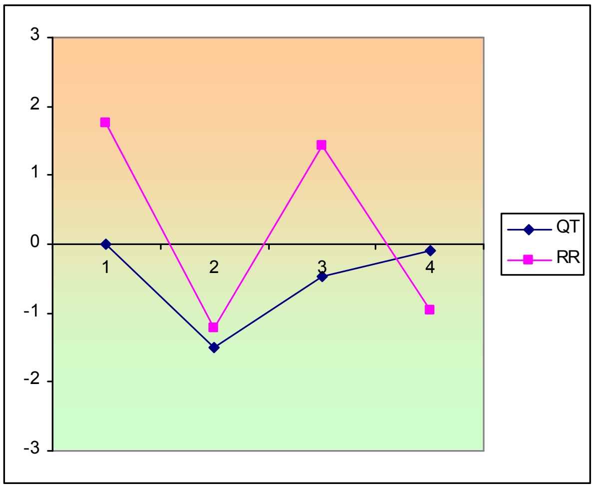

Fig. 4 Stability RR and QT intervals for cosmonaut A data

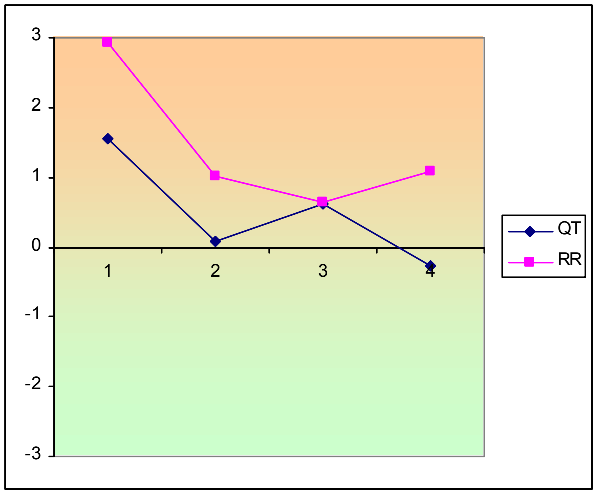

Fig. 5 Stability RR and QT intervals for cosmonaut B data

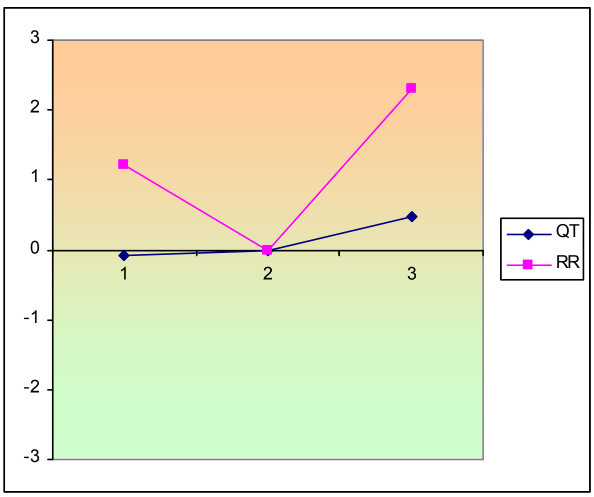

Fig. 6 Stability RR and QT intervals for cosmonaut C data

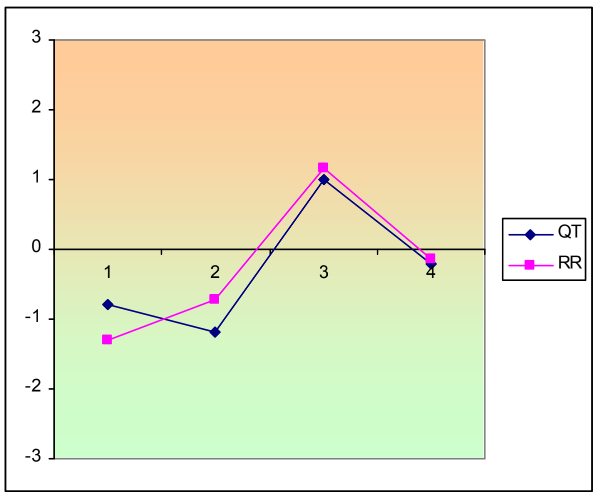

Fig. 7 Stability RR and QT intervals for cosmonaut D data

There is good correlation between results for RR and QT stability analysis: Pearson correlation coefficient $r = 0.75$ and Spearman rank correlation $R = 0.7$. This is like the results of M-index calculations for RR and QT where $r = 0.79$. Weak correlation shown by comparison of results of the M-index nonlinear analysis and stability analysis: Pearson correlation coefficient for RR data is $r = 0.09$ and for QT data is $r = 0.28$ Thereby we show that stability analysis is quantitatively different from M-index nonlinear analysis and both analyses are supplementing each other.

First of all, we should ascertain that in all cases QT intervals behaviour is more stable (mean value -0.06) than RR intervals behaviour (mean value 0.6). Secondly – space flight disturbances often put cardiovascular system in transition state.

The last but not the least we note on the qualitative level that stability analysis show like in M-index nonlinear analysis two groups of stability behaviour:

return to stability zone after space flight disturbances (compensate motion) – cosmonauts A and D; unstable behaviour up to the end of observation period (decompensate motion) – cosmonauts B and C. We make special emphasis on the fact of coincidence of cosmonauts groups in both analyses – nonlinear and stability.

IV. DISCUSSION

The short cardiovascular variability records especially heart rate variability are unstable in additional to non-stationary. This strengthens our previous result from nonlinear analysis that heart rate variability for short records are poor for analysis by standard spectral methods and the better results can be obtained by analysis of QT intervals variability. The stability and nonlinear analysis give different result in a quantitative sense but comparable on the qualitative level. Both analyses – nonlinear and stability complete each other.

V. CONCLUSIONS

The present study introduces M-index stability analysis for cardiovascular oscillations. We have showed that QT intervals behaviour is more stable than RR; space flight disturbances put cardiovascular system in transition state; stability of cardiovascular oscillations has strong individual behaviour that can be consolidated in common behaviour groups. These groups coinside for nonlinear and stability analysis. We can note in additional that in group with uncompensated motion case B show movement into stable direction unlike C. Thus stability analysis shows direction in time series behaviour but nonlinear indicate only if current state is stationary or not.

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