Heart Rate Variability Expressed by Poincaré Plot in Metabolic Syndrome

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Abstract. *Heart rate variability, considered as an indicator of autonomic nervous function shows differences between healthy persons and patients with metabolic syndrome. Data from 40 patients with metabolic syndrome and 48 healthy subjects were obtained. Poincaré plots and calculated indexes SD1 and SD2 were used to evaluate the differences between heart rate variability in these two groups. The SD1 and SD2 showed lower values during rest in patients with the metabolic syndrome and a smaller decrease of these parameters occurred during the tilt relative to the control group. This change can be expressed by the difference ΔSD1 and ΔSD2 before and during the tilt. In conclusion, the ΔSD1 obtained from a signal measured in tilt in controlled breathing of 20 times per minute may perhaps help to distinguish between healthy persons and patients with the metabolic syndrome if it is correctly used.*

Keywords: heart rate variability; metabolic syndrome; Poincaré plot

1. Introduction

The heart rate variability (HRV) is considered too be an important tool for the study of autonomic nervous functions. There are several methods for HRV analysis: linear and nonlinear, in time domain or in frequency domain. In this study was used the Poincaré plot, a graphical method belonging to time domain analysis. It stands on the border between nonlinear and linear methods as discussed in [1]. A typical Poincaré plot is constructed as a relationship between RR_i (x-axis) and RR_{i+1} (y-axis), which means that each point in the plot corresponds to two consecutive RR intervals [1], [2].

HRV analysis can be of help also in the study of the metabolic syndrome (MetS), which is defined by a set of multiple metabolic abnormalities associated with cardiovascular diseases [3], [4]. The main risk factors accepted as a part of this syndrome are central obesity, insulin resistance, hyperglycemia, hypertension, and dyslipidemia [3], [5]. There are many different approaches for common classification criteria of MetS [4]. The most used of them are the criteria defined by the U.S. National Cholesterol Education Program, often denoted just as ATP III (Third Adult Treatment Panel) [3]. This standard was also used in this study.

A significant aspect of MetS is a diminished autonomic cardiovascular control which is observed as lower HRV values [6-10]. In almost all of these studies HRV was measured using traditional linear parameters like the time domain statistical methods and spectral analysis, except of the study [8]. Here were used also non-linear parameters, like short-term fractal scaling exponent of detrended fluctuation analysis (DFA-1) and power law slope.

The data in this study were originally obtained in order to examine changes in autonomic functions in patients with MetS for the doctor thesis [10]. This study evaluated blood pressure, pulse pressure, change of pulsatile impedance signal, RR intervals, baroreflex sensitivity, heart rate and blood pressure variability. Hereby, HRV was only evaluated using frequency analysis.

2. Subject and Methods

Subjects

Data were obtained from 40 patients with MetS and from 48 healthy subjects in the First Internal Cardioangiology Clinic, St. Anna's University Hospital Brno. The measuring protocol included 5 min in a horizontal position, followed by an 8 min tilt (75°) and again 5 min in the horizontal position [10]. The controlled breathing of the subjects was 6 times per minute (tilt6) and 20 times per minute (tilt20) respectively.

Poincaré plot

The Poincaré plot was constructed from 5 min intervals before, during and after the tilt for all subjects in all measurements and the parameters SD1 and SD2 were calculated.

The typical shape of a Poincaré plot is an elongated cloud of points (see Fig. 1.) around the line-of identity (LoI).

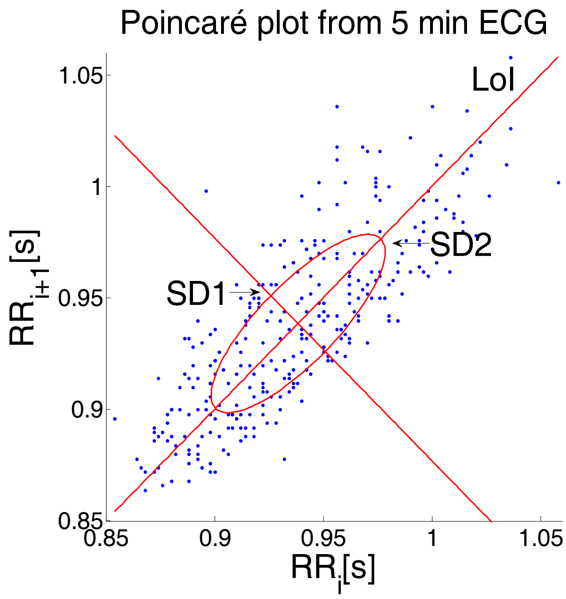

Fig. 1. Poincaré plot from a 5 min record of ECG signal from before tilt (tilt6) in a healthy person.

The shape of the plot can be evaluated visually or numerically. For the numerical evaluation in this study the popular ellipse fitting technique was used. The ellipse minor axis perpendicular to LoI is identical with the standard deviation SD1 and represents the short term variability [1], [2]. The major axis, which is represented by the standard deviation SD2, represents the long term variability. In this study, for the calculation of SD1 and SD2 the equations stated in [2] were used.

3. Results

The SD1 and SD2 showed lower values in rest by patients with MetS and also a smaller change of this parameters occurred during the tilt. In order to better express this change, the difference of SD1 and SD2 before and during the tilt was calculated for each subject. The average values of ΔSD1 and ΔSD2 are in Table 1.

Some values calculated from some subjects had to be omitted because of errors in Poincaré plots due to detection errors of the R wave or heavy ectopic activity. Another problem were also the not long enough stable sections before or during the tilt. To eliminate outliers the Grubbs` test and Dixon test was used on the $\Delta SD1_i$ and $\Delta SD2_i$ values. All the finally used groups for the computing of the average ΔSD1 (or ΔSD2) had statistically significant differences between SD1i (or SD2i) before and during the tilt (Wilcoxon's matched-pairs signed-ranks, $p<0.05$).

Comparing the values from Table 1, the most visible contrast is between healthy persons and patients with MetS in the case of ΔSD1 in tilt20. In this case we found statistically significant differences $\Delta SD1_i$ (Mann Whitney, $p=0.03$) between healthy persons and patients with MetS.

Table 1. Average values of ΔSD1 and ΔSD2 for the selected set of the healthy control group (Control) and patients with the metabolic syndrome in tilt6 and tilt20 test.

	tilt6_ΔSD1 [ms]	tilt20_ΔSD1* [ms]	tilt6_ΔSD2 [ms]	tilt20_ΔSD2 [ms]
Control	5.69 (sd. 8.63) N = 25	12.15 (sd. 11.10) N = 30	7.81 (sd. 15.07) N = 25	5.01 (sd. 11.91) N = 30
Metabolic syndrome	4.19 (sd. 4.05) N = 22	5.58 (sd. 4.82) N = 33	6.49 (sd. 10.2) N = 22	4.02 (sd. 6.19) N = 31

sd. – standard deviation, N – number of subjects in group, * Mann-Whitney U test $p<0.05$

Calculation of SD1 in time (1 min intervals) showed that the short-term variability decreases faster and more in healthy persons than in the metabolic group when changing the position from horizontal to tilt and afterwards increases again faster when changing the position back to horizontal.

4. Discussion and Conclusions

From the results it is visible that the decrease of SD1 and SD2 in MetS is smaller than in healthy persons. Statistically significant were just the differences $\Delta SD1_i$ during controlled breathing 20 times in minute ($p=0.03$). This breathing frequency (approximately 0.33 Hz) intervenes with the high frequency area (HF 0.15-0.4 Hz) of the HRV spectrum. The parameter SD1 represents fast changes in HRV so it is connected to the HF, which could be a reason why ΔSD1 response in tilt20 so strongly. Further on, by comparing the values of SD1 of the individual subjects there was clearly noticeable that the dispersion of the values before tilt is much higher than during the tilt in tilt20 measure. In the case of tilt6 this phenomenon is not significantly visible.

The high values of standard deviations are most likely due to the interindividual variation of other parameters influencing the HRV, which were not taken in account and represent a limitation of this study.

In the doctor thesis [10] lower values of HRV were expressed by indicators in spectral analysis in patients with MetS than in healthy persons, which is in accordance with findings in this study. Further on, it is pointed out that the breathing frequency of 6 times per minute enhanced the difference between healthy persons and patients with MetS. By this breathing frequency the average values of HRV spectra in low frequency (LF 0.04-0.15 Hz) and HF increased very markedly in the case of healthy persons as compared to MetS instead of decreasing as by tilt20. In our study, a significant difference showed just by ΔSD1 tilt20. Also according to the average values there is just a decrease in the HRV indicators during the tilt and no increase as reported in [10]. But in individual cases there were some, where the HRV parameters increased instead of reducing. This happened in much more cases by SD1 during tilt6 than tilt20. This is probably also a reason why ΔSD1 was significant by tilt20 but not by tilt6. It is discussed in [10] that by the breathing frequency of 0.1 Hz (6 per minute) breathing influences the baroreflex by coming into a resonance with the internal baroreflex frequency of 0.1 Hz and invokes in this way a high response.

Other studies observed statistically significantly lower values in LF and HF in patients with MetS as compared to healthy persons [6] and [9]. In [7] the LF and HF were not significant instead lower values of SDNN (standard deviation of normal RR intervals) and very low frequency in patients with MetS were here significant. These studies used different lengths of recorded data (2-5 min) and diverse compositions of the studied groups. Study [8] cannot be accurately compared with this or the other mentioned studies because it was performed on long-term recordings.

In conclusion, ΔSD1 obtained from a signal measured in the tilt experiment using controlled breathing of 20 times per minute may perhaps help to distinguish between healthy persons and patients with MetS, if other interindividual parameters are also considered.

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