Impact of the temporal series length on the Heart Rate Variability analysis of congestive heart failure

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***Abstract**. Heart Rate Variability has been reported as a very simple and adequate methodology to evaluate the homeostasis of an individual. It can easily be measured by recording the RR interval from a heart generated signal, which can be performed by a noninvasive procedure with, for example, Holter or Polar cardiac monitors. In this work it is determined by using Poincaré plot parameters the shortest size a time series of RR intervals should have to statistically represent the measured data of longer series. The results show that series with 250 RR intervals maintain very good correlation (for SD1 and SD2) when compared with series containing up to 75,000 intervals. For the ratio SD1/SD2 the correlations are kept high up to series with 5,000 intervals.*
Keywords: heart rate variability, Poincaré plot, length of time series, congestive heart failure.

Impacto da extensão das séries temporais na análise da Variabilidade da Freqüência Cardíaca em pacientes com falha cardíaca congestiva

Resumo. A Variabilidade da Freqüência Cardíaca (VFC) é uma medida simples para avaliar a homeostase de um indivíduo. A VFC facilmente pode ser medida pela variação dos intervalos RR captados do coração, através de um procedimento não invasivo, por exemplo, monitores Holter ou Polar. Nesse trabalho, determinamos os parâmetros do gráfico de Poincaré para a menor série temporal de intervalos RR que pode representar estatisticamente a mesma série temporal em tamanho maior. Os resultados mostram que séries temporais com 250 intervalos RR mantém uma boa correlação (para SD1 e SD2) comparados a séries com 75.000 intervalos. Para a razão SD1/SD2 as correlações são altas somente para séries com mais de 5.000 intervalos.
Palavras-chave: variabilidade da freqüência cardíaca, gráfico de Poincaré, comprimento das séries temporais, falha cardíaca congestiva.

1. Introduction

Cardiac measuring devices, either Holter [1,2] or Polar monitors [3,4] produce time series of RR intervals, while reflecting heartbeats, allow analysis of alterations in the homeostasis of an individual [5]. Depending on acquisition time and specific conditions of the individual, time series of the RR intervals or tachograms may have different extensions. For example, it is more difficult to assess the heart rate reliably in premature newborns [6] than in adults. On the other hand, it is expected that the analysis of tachograms with longer extension might contain more information, regardless of the difficulty in collecting the RR signal. Therefore, it is important to establish the minimum extension of the time series to statistically represent the counterpart series with longer extension.

In the study of heart rate variability several measures in time and frequency domains as well as in the nonlinear or chaos domain can be used. The present study uses descriptors derived from the Poincaré plot, which have characteristics of both time and nonlinear domains.

By this way, and based on comparative analysis of a set of shorter and longer series (250 to 75,000 or more intervals), the goal of this work is to determine by using the Poincaré plot parameters SD1, SD2, SD1/SD2 [7], the shortest size a series should have to statistically represent the measured data and to retain the ability to discriminate relevant clinic events.

2. Methodology

2.1. Database

From Physionet database [8], twenty nine RR time series were obtained from patients with congestive heart failure (CHF), aged between 34 and 79 years, collected by Holter monitoring over 24 hours (Marquette 8500 Holter) [1,2]. This made possible the preparation of time series with progressively longer extensions containing 250, 500, 1, 2, 3, 5, 10, 25, 50, 75 thousand and exceeding 75,000 RR intervals.

The impact of the extension of time series on the analysis of variability of the heart rate was evaluated through comparison of intragroups. For this analysis, the variables SD1, SD2 and SD1/SD2 were selected (see Section 2.2).

2.2. Poincaré plot

The Poincaré plot is a method of analysis based on linear and nonlinear dynamics, whereby each value (an RR interval) of the analyzed series is plotted against the previous value.

This method has been used in studies of heart rate variability (HRV) [5,7,9,10], considered an important method with nonlinear features to enable analysis by visual inspection summarizing a series of RR intervals in a figure. Moreover, the Poincaré plot is also a technique that provides quantitative information about the behavior of short-HRV (SD1) and long (SD2) durations [9].

According to Piskorski and Guzik (2007) the Poincaré plot of RR intervals is composed of points (RR_i, RR_{i+1}), where a pair of consecutive RR intervals specifies a coordinate point in the graph (see Figure 1). Among other measures, from the graph the following parameters can be extracted: X1, X2, centroid, SD1, SD2 and SD1/SD2. Figure 1 shows a sample chart with the Poincaré parameters mentioned above.

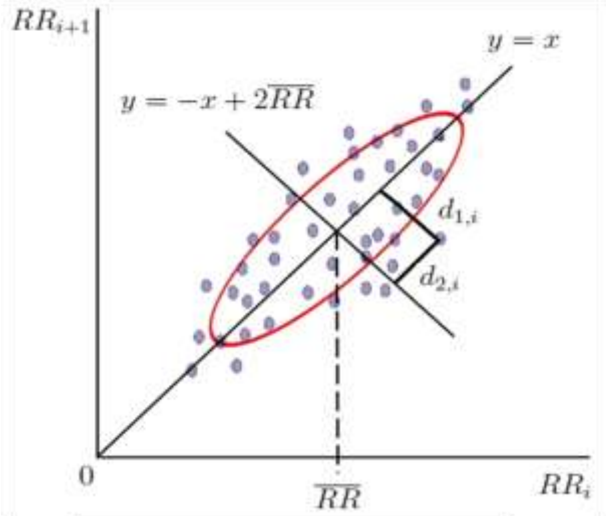
The Poincaré plot parameters used in this work are directly related to the physiology of the heart and to the autonomic nervous system. The parameter SD1 relates to the short range of RR intervals, reflecting the variability of successive intervals, connected to the parasympathetic control of sinus node, whilst SD2 relates to long range RR intervals, correlated to the sympathetic control sinus node by the autonomic nervous system [11].

Some works have analyzed HRV variables for understanding the physiological and biological phenomena occurring during physical training [11] in patients with congestive heart failure [12] and during the practice of meditation [13].

2.3. Statistical analysis

The data were evaluated using Pearson's correlation coefficient. In our case, the Pearson's correlation coefficient is a measure of linear dependence (correlation) between two time series with length difference.

It is considered that the correlation coefficient values are very high for *r* from 0.9 to 1. Values between 0.7 and 0.89 indicate a high correlation, and 0.5 to 0.69 are assigned to a moderate degree. Finally, correlations between 0.3 and 0.49 are considered low and less than 0.3 are called minimal.



$$d_{1,i} = \frac{1}{\sqrt{2}}(RR_i - RR_{i+1})$$

$$SD1 = \sqrt{Var\{d_{1,i}\}}$$

$$d_{2,i} = \frac{1}{\sqrt{2}}(RR_i + RR_{i+1} - 2\overline{RR})$$

$$SD2 = \sqrt{Var\{d_{2,i}\}}$$

Figure 1: Example of Poincaré plot obtained from a tachogram. The parameters extracted from the graph are: X2 (line identity), X1 (perpendicular to the line identity), centroid (intersection of the means of *x*-axis (RR_1, RR_2,..., RR_n) and the *y*-axis (RR_2, RR_3,..., RR_{N+1}), SD1 (standard deviation over X1) related to short-term HRV, SD2 (standard deviation over X2) related to long-term HRV and SD1/SD2 (ratio of short and long range variations).

3. Results

The analysis was based on 29 tachograms of patients with congestive heart failure, captured in the database Physionet. The measure of the impact of the extension of the time series was made by using Pearson's correlation.

It was found that the variable SD1 maintained excellent correlation, from very small sets of extensions (250 intervals) to over 75,000 intervals, thus indicating that this variable can be compared in different studies of the literature, even if the length of time series in each of them are quite different from each other.

For the variable SD2, the correlations were also quite high although not as much as for SD1, keeping the value of the correlation coefficient always above 0.6 and often exceeding 0.9. But for the ratio SD1/SD2, the correlations were lower showing clearly two separated rectangular regions (250 to 5,000 and 5,000 to >75,000 intervals) where the short and long series correlate with themselves. Thus, series with 250 to 5,000 intervals maintain a good correlation with a series of RR intervals until 5,000, but above this limit the correlation is lost with resulting correlation coefficients around 0.30 (see Figure 2).

4. Conclusions

Based on Poincaré plot parameters SD1, SD2, SD1/SD2 of a set of shorter and longer series (250 to 75,000 or more intervals), the goal of this work was to determine the shortest size a series should have to statistically represent the measured data.

The results showed that series with 250 RR intervals maintain very good correlation of results (for SD1 and SD2) at ranges up to 75,000 intervals. For the SD1/SD2 ratio, correlations remained high up to 5,000 intervals.

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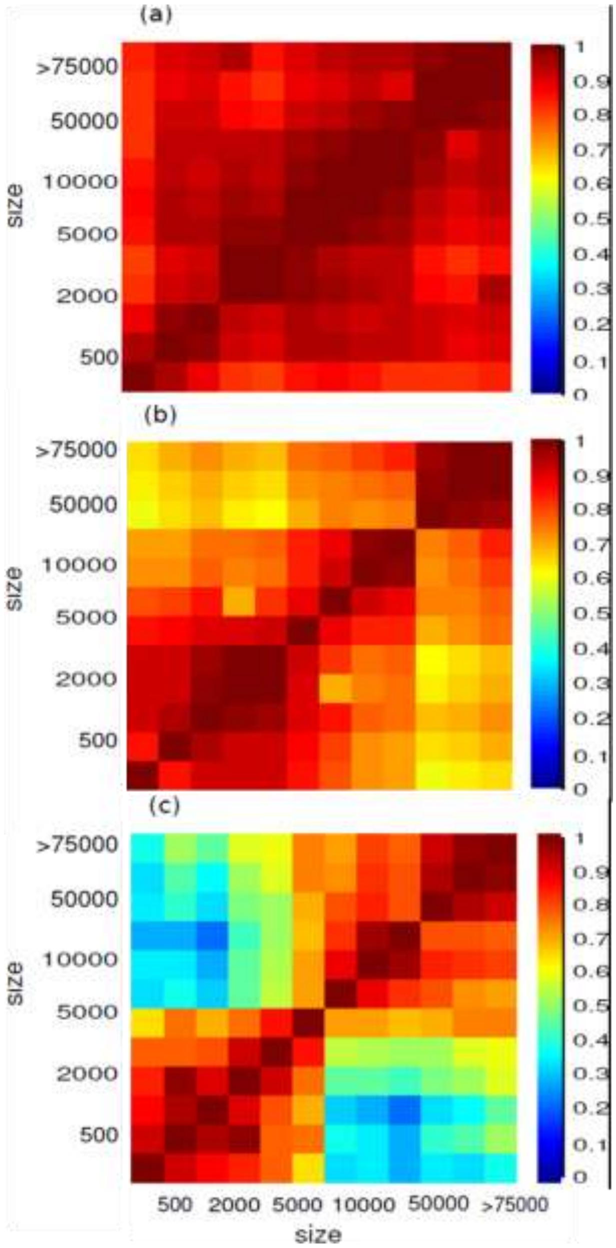

Figure 2: Test of Pearson's correlation for the Poincaré plot parameters (CHF set) in a comparative analysis of other small series with progressively larger series. The color scale on the right indicates the degree of correlation. (a) SD1 parameter, (b) SD2 and (c) SD1/SD2.

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