The Dimension of 2D and 3D Poincaré Plots obtained from 24 Hour ECG Registrations

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Abstract

The dimension is a basic concept in non linear dynamics. The box counting dimension (BCD) is one of the methods that is available to determine the dimension. We studied the dimension of the heartrate signal in both 2 and 3D Poincaré plots in a group of twenty five post myocardial infarction (MI) patients together with an age and sex matched control group. The average BCD from the normal subjects based on a 2D first return plot was 1.46 ± 0.09, while in the infarction group this was significantly lower: 1.34 ± 0.17 (p=0.003). Excluding ectopic data from the analysis caused large changes in the resulting dimension.

1. Introduction

Heart Rate Variability (HRV) is used to study regulatory systems of the Heart. The result of the HRV computation may be used as a predictor for the outcome in several patient categories[1]. For this purpose, linear as well as non-linear methods have been used. When using non-linear techniques, the concept of dimension plays an important role. The dimension is the number of variables that is needed to specify a point in an object. For a Euclidean object such as a square the dimension would therefore be 2. The box counting dimension (BCD) is a fast and easy to use alternative for the more classic measures such as the Hausdorff and correlation dimension. An example of a Poincaré plot is shown in figure 1. These plots are the basis for the BCD computation in this study. The length of the current interval (RRn) is shown on the X-axis while the length of the previous interval is shown on the Y-axis (RRn-1). When using linear HRV methods non sinus intervals (NSI) are either replaced or excluded. [2].

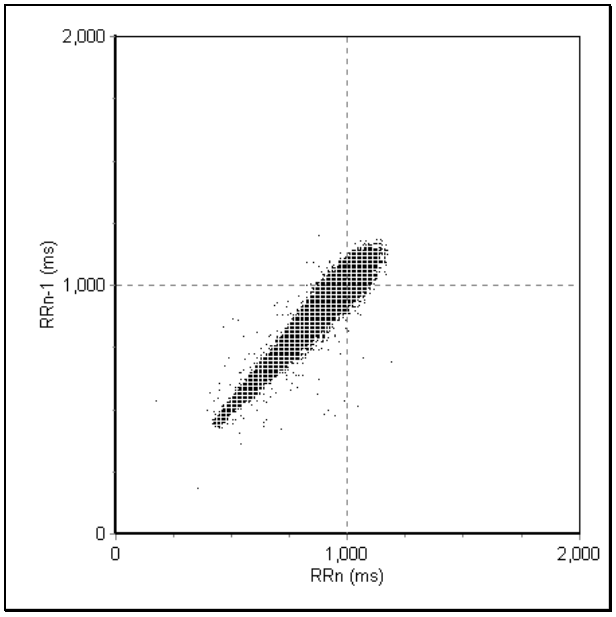

Figure 1. A Poincaré or first return plot of a normal subject.

When using spectral analysis, a technique that requires an uninterrupted signal, NSI are substituted. A paucity of data exists that demonstrates the effect NSI on linear HRV measures: too much NSI leads to unreliable results. This is not only caused by the fact that the amount of substitution increases but also because the accuracy of a Holtersystem is limited. Since Holtersystems do not detect P-waves, supraventricular ectopic activity is detected by means of a prematurity cutoff point. Normal QRS complexes > x % premature are considered of ectopic origin, while all QRS complexes <= x % are considered to be irregular sinus rhythm. Some Holtersystems do not offer the possibility to adjust this prematurity setting, while others allow only changes with a stepsize of 5 %. Furthermore in many registrations there is not a clear cutoff point but a trajectory in which both supraventricular ectopics and

sinusrhythm occurs. Also an accurate quantification of ventricular complexes is not always possible, especially when fusion complexes occur of then a patient has wide QRS complexes. The fact that high risk patient groups, such as post MI patients or patients with chronic Heart failure have frequent arrythmias limits the suitability of these techniques. If a HRV technique would be applicable even in patients with a high incidence of ventricular arrhythmia this would be a major advantage. The present study aims to compare the discriminating value of 2D and 3D first return plots between two groups of patients as well as to describe in what way the prevalence of ectopic activity influences these measures.

2. Methods

Ambulatory monitoring was performed using a Marquette series 8500 Holter recorder. Only recordings with sinus rhythm and a duration longer than 20 hours were included. All recordings were carefully analyzed by an experienced analyst using a MARS ® Holtersystem The ECG was visually checked for ectopic beats and episodes with noise. After analysis, the beatstream of RR intervals was transferred to a PC. A custom built software package for time series analysis (COHWIN) was used to create graphical representations of the EKG and to perform data analysis. The COHWIN package is written in Delphi™. The study population consisted of 25 male subjects approximately 6 weeks post MI, age 57 ± 11(mean ± SD). As a control group an sex and age matched group of 25 healthy men age 52 ± 5 was taken. SPSS 11.01 was uses for statistical analysis.

2.1. 2D Poincaré plot

In a 2D Poincaré plot, the length of the current RR interval is plotted against the length of the previous interval (see fig1). By using this type of 2D representation of the signal just the length of the intervals is taken into consideration, not the quantity of intervals that occur.

2.2. 3D Poincaré plot

In the 3D Poincaré plot that we used plot the amount of intervals was plotted on the Z-axis. This form of representation not only takes the length of intervals into account but also includes the amount that occurs. Because of the 3D character of this representation, boxes in stead of squares are used to determine the BCD.

2.3. Box counting dimension

Based on these Poincaré plots the BCD was calculated. In order to do this the map was covered with squares of edge-length ε_0 and the count of boxes that contained a point was called $N_{(\varepsilon_0)}$. This step is repeated with squares that have an edge-length of $\varepsilon_1 = \frac{\varepsilon_0}{2}$. This process is repeated until reducing the size of the square was of no use anymore. Since the sampling frequency of the Holtersystem was 128 Hz the minimum boxsize was 1000/128 = 7.8125 ms.

The BCD may be determined as $D = \frac{\log N(\varepsilon_{i+1}) / N(\varepsilon_i)}{\log \varepsilon_i / \varepsilon_{i+1}}$ [1,2].

3. Results

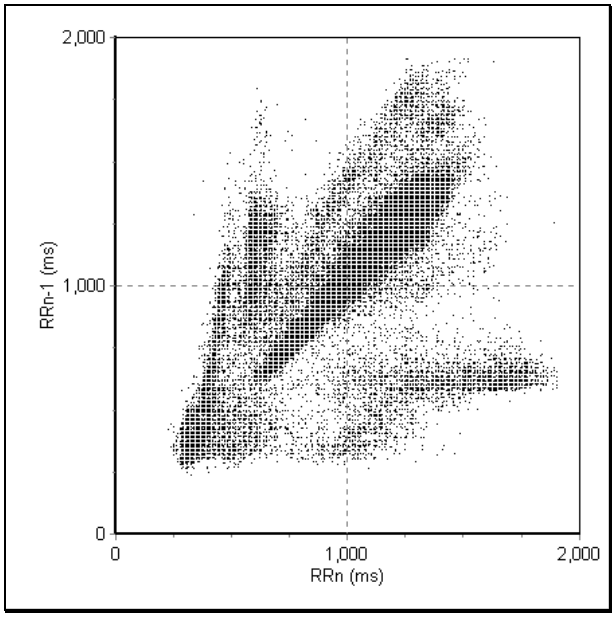

Figure 2a. First return plot of a post myocardial infarction patient.

Figure 2a shows a first return plot of a post MI patient with frequent ventricular premature contractions. The strong side lobes of this graph represent the frequent ventricular arrythmias that were present in this recording. Figure 2b shows the same recording. This time ectopic beats are not plotted. Only the center part of the graph remains, representing the activity of the sinus node.

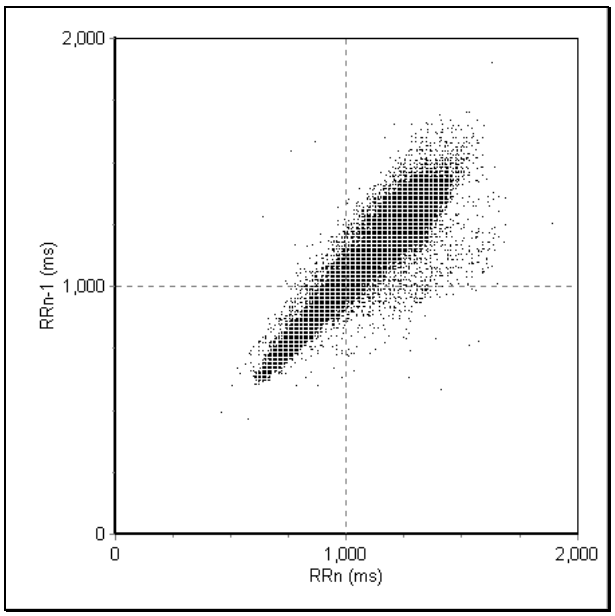

Figure 2b. First return plot without ectopic beats.

Table 1 shows the time domain variables and the amount of ventricular as well as supraventricular ectopic complexes.

	Post MI	Normals
AVGNN (ms)	966	848
SDNN (ms)	137	150
RMSSD (ms)	37	33
V-ectopics	265	217
SV-ectopics	236	255

Table 1: Time domain HRV variables and amount of ectopic complexes for both groups AVGNN: average normal-to normal interval. SDNN: Standarddeviation of normal-to-normal intervals. RMSSD: root mean square of successive differences. For further explanation on these variables see[1].

	Normals	Post MI	p- value
2D all beats	1.46 ± 0.09	1.34 ±0.17	0.003
2D no ectopy	1.55	1.51	Ns
p-value	< 0.001	< 0.001	

Table 2: BCD with and without ectopics.

Table 2 shows the results for the BCD and the statistical difference. Including all beats in a 2D Poincaré plot led to the highest discriminating situation 1.46 for the normal subjects and 1.34 for the post MI group. (p=0.003).

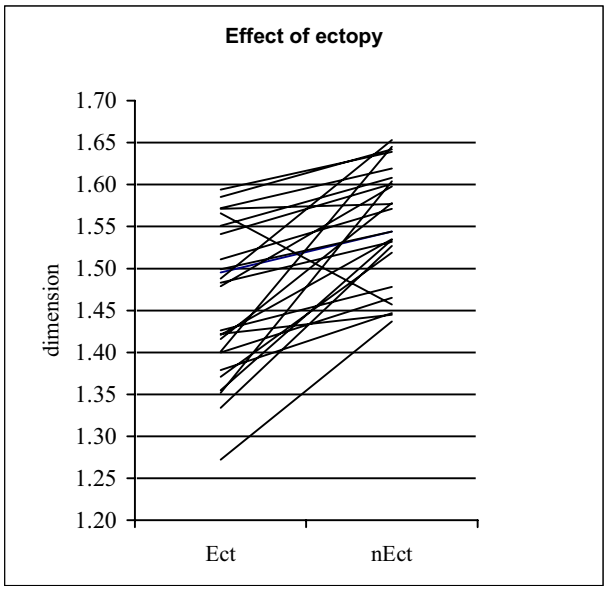

Figure 3. The effect of excluding the ectopic beats in the normal group. (Ect = with ectopics, nEct = without ectopics)

When the amount of intervals was introduced as the third dimension the difference between normal subjects and post MI patients disappeared: (1.91 ± 0.05) for both groups. Excluding the ectopic beats the BCD increased in all but one normal subject. This increase was statistically significant ($p < 0.001$ for both groups) However the difference between the groups was no longer significant (see table 2). In figure 3 all subjects, excepts one demonstrate an increase in the BCD when ectopic data is excluded. Observation of data revealed that this was a normal subject with a high incidence of ectopic beats (> 8300). Inspection of the first return plot (see figure 4) shows two large side lobes at both the left and right side of the central part. This suggests that not all ectopic beats have been properly identified.

4. Discussion

The average heartrate was lower in the post infarction patients compared to the normal group. This may be explained by frequently used betablocker therapy. This is confirmed by the time domain variables that show a lower SDNN and a higher rMSSD. As expected the prevalence of ectopic beats was somewhat higher in the post MI group compared to the normal subjects. Figure 2a and 2b demonstrate clearly the effect of ectopic activity on the signal composition. After removal of the ectopic beats no difference remained between the post

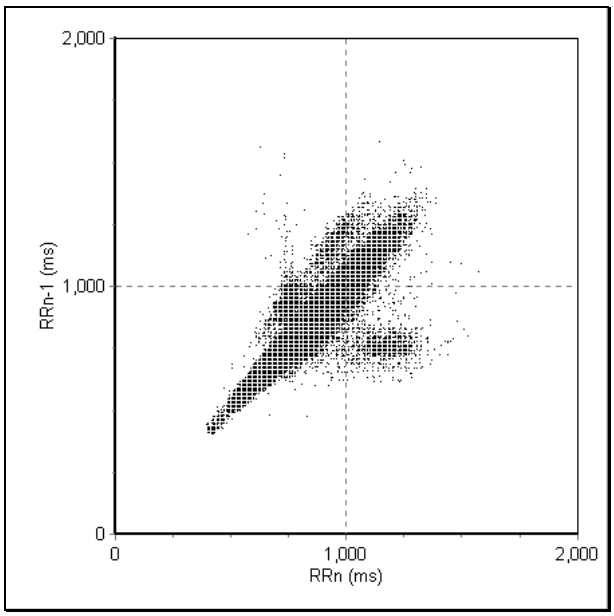

Figure 4: Poincaré plot with ectopy excluded The geometric form of the plot suggests that not all ectopic data has been properly identified.

MI patients and the control group. This suggests that the difference in BCD is explained by the prevalence of ectopy rather than by difference in heart rate or medication. Whether this means that the BCD has an additional prognostic value need to be investigated.

5. Conclusion

Including the amount of intervals as the third dimension in the computation of the BCD does not improve the discriminating value of this parameter in separating post MI patients from normal subjects. The ectopic beats contribute to the "complexity" of the signal, therefore exclusion of these beats leads to loss of information. When ectopic data is not properly identified this may lead to large differences in the BCD. Even when all beats are included, adequate analysis of Holter ECG's remains necessary.

Acknowledgements

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