NON-LINEAR STRUCTURE ANALYSIS OF INTER-BEAT INTERVAL DATA IN PATIENTS AFTER MYOCARDIAL INFARCTION

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A b s t r a c t

The aim of the present study was to test reliability of the "fast scaling index method" of non-linear dynamics (chaos theory) of heart rate variability. Holter 24-hour ECG recordings in patients after myocardial infarction were analysed. The scaling index alpha, i.e. the state distribution of successive RR intervals in phase space, was calculated for 500 beats at the beginning of each hour and the N(alpha) histogram was constructed as a sum of 24 histograms. The difference between the alpha value calculated for the peak of sinus rhythm and that for ectopic beats was determined. The reliability of this fast method was tested by a comparison of each 24-hour histogram with three relevant 6-hour histograms (night, morning and afternoon). No difference was found in the delta alpha determination from 24-hour and 6-hour periods. The time of recording (morning, afternoon, night) did not play any role, either. It is concluded that this fast scaling index alpha method is suitable for clinical practice.

K e y w o r d s

heart rate variability, myocardial infarction, chaos

INTRODUCTION

The methods of nonlinear dynamics have opened new and fundamentally different ways to the analysis of heart rate variability and cardiac arrhythmias *(1).* One of these new techniques is the „scaling index method“ which can separately quantify the complexity of sinus rhythm and that of ectopic beats *(2).* The scaling index alpha is calculated for every beat and a variation N(alpha)histogram is determined. The difference between alpha(sr) for the peak of sinus rhythm and the alpha(es) peak for ectopic beats [delta alpha = alpha(es) - alpha(sr)] correlates with the risk of sudden cardiac death. The disadvantage of this method is the vast computer time consumption. We suggested a fast method with lower requirements for both hardware and software and the aim of this study was to test its reliability.

MATERIALS AND METHODS

A Holter 24-hour ECG recording was taken in each of 15 patients included in this study, 7 to 14 days after the first signs of myocardial infarction.

The scaling index alpha makes use of the state distribution in phase space. It is calculated by counting the number of states N, which occur within a 3-dimensional sphere of radius r around a point i, located in the phase space cube. Every point i corresponds to a beat with three successive RR intervals (preceding RR interval, pre-preceding RR interval and pre-pre-preceding RR interval) plotted along three perpendicular axes of the phase space cube. For each beat we calculated the distances between beat i and all other beats in this phase space. We then determined the curve of a relationship between ln(N) and ln(r), where N is the number of beats with distances shorter than r, i.e., the number of points which are inside a sphere with the centre in point i and with radius r in the phase space. The scaling index alpha is calculated as the difference of ln(N) at ln(r1) = 6.8408 (ln(r1) =0.9*ln(rmax); rmax = 2000 ms) and ln(N) at ln(r2) = 1.5201 (ln(r2) = 0.2*ln(rmax)) divided by the difference between ln(r1) and ln(r2). The alpha is calculated for each beat i and the N(alpha) histogram is subsequently calculated for the whole recording.

In the classical approach, this analysis is made for the whole signal of RR-intervals, which is 24 h long.

We developed a fast method based on the analysis of 500 beats recorded at the beginning of each hour. This provided 24 N(alpha) histograms which were summed up to give one 24-hour N(alpha) histogram. The reliability of this fast method was tested by comparing this 24-hour histogram with three 6-hour histograms (night, 11 p.m. to 5 a.m.; mornig, 7 a.m. to 1 p.m; afternoon and evening, 3 p.m. to 9 p.m.). The difference between the alpha value calculated for the peak of sinus rhythm and that for ectopic beats was determined.

RESULTS

In the group of 15 patients, there was no difference in the characteristics, based on the presence and value of delta alpha, among the 24-hour and 6-hour N(alpha) histograms. The time of recording (morning, afternoon, night) appeared to have no effect on this difference, either. The examples of the analysis are in *Fig. 1*.

DISCUSSION

In the recent years, the chaos theory has been applied to the analysis of biological systems *(3, 4)*. Up to now, pathophysiological mechanisms responsible for arrhythmia complexity variations observed have been only speculative. It is probable that the complexity of arrhythmias is linked to the underlying electrophysiological mechanism. According to this view, low complexity arrhythmias relate to a stable electrophysiological substrate (probably a reentry within a stable myocardial scar), whereas high complexity arrhythmias indicate an unstable substrate (e.g., transient ischaemia, early and late after-depolarisation). The complexity of arrhythmias, determined as the delta alpha index, is different from the concept of the Lown classification (2). The advantage of this structural complexity measure is that the complexity is determined by one value only.

Morfill et al. (5) reported that, in their clinical study comprising 30 patients with a high risk of sudden cardiac death, 14 died during 8 years, 16 remained alive and 10 did not complete the study for various reasons. All patients had more than 10 ventricular extrasystoles per hour and ejection fraction less than 50% . In other studies, the complexity measure was a better index for discrimination between

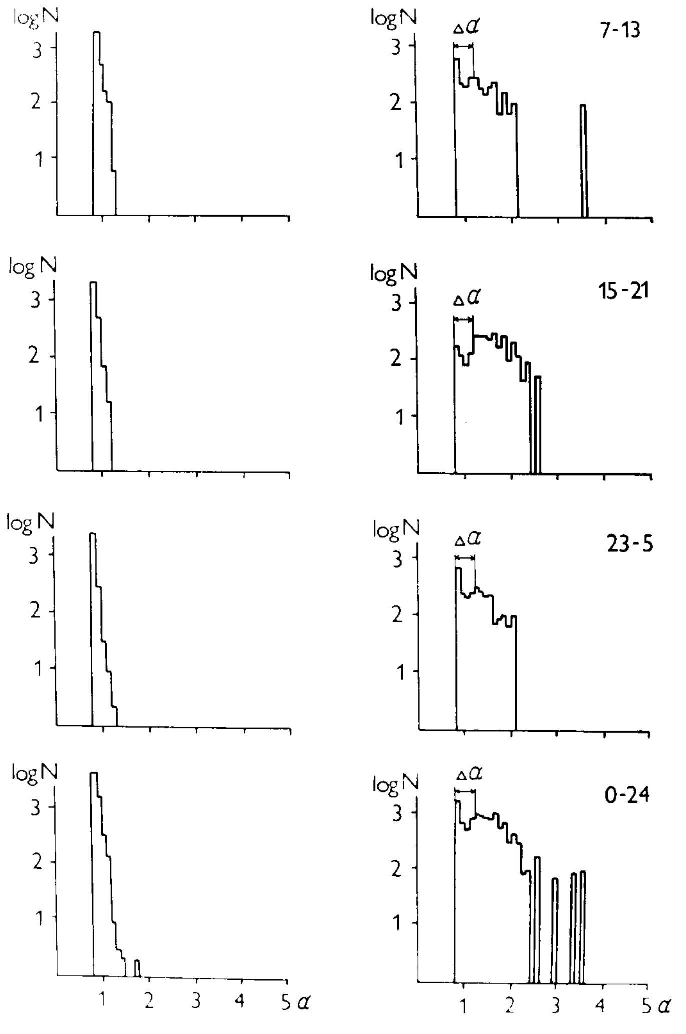

Fig. 1

Examples of N(alpha) histograms in two patients after myocardial infarction. Left column, patient with a low number of premature ventricular contractions; right column, patient with a high number of premature ventricular contractions; N, number of beats; alpha scaling index, the complexity of sinus rhythms related to the number of ectopic beats; 7-13, 15-21, 23-5, 0-24, daily intervals of measurement.

deceased and surviving patients than heart rate variability measurement *(6, 7).* In our laboratory we have used a set of non-invasive tests for the assessment of sudden cardiac death risk. We have examined not only 24-hour ECG and ejection fraction but also late potentials and baroreflex sensitivity *(8).*

It is concluded that the modified analysis as described in this paper offers a convenient tool for determination of the index alpha in clinical practice. A comparison of this complexity measure with the set of tests used previously is needed and this fact warrants further investigations in this field.

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NELINEÁRNÍ STRUKTURNÍ ANALÝZA TEPOVÝCH INTERVALŮ U NEMOCNÝCH PO INFARKTU MYOKARDU

S o u h r n

Cílem studie bylo testování spolehlivosti „rychlé metody určení normalizovaného indexu“ z oblasti nelineární dynamiky (teorie chaosu) variability srdeční frekvence. Analyzovali jsme Holterův 24-hodinový záznam EKG u pacientů po infarktu myokardu. Normalizovaný index alfa, odpovídající distribuci stavů následných RR intervalů ve fázovém prostoru, byl počítán pro 500 tepů na začátku každé hodiny a histogram N(alfa) byl sestrojen jako sumární z 24 histogramů. Spolehlivost „rychlé metody“ byla testována srovnáním 24-hodinového histogramu se třemi šestihodinovými histogramy (noc, dopoledne a odpoledne). Určili jsme rozdíl mezi delta alfa z různých záznamů. Nenašli jsme rozdíl v delta alfa určením z 24-hodinové periody a z šestihodinových period. Rovněž doba záznamu (dopoledne, odpoledne, noc) nehrála úlohu. Uzavíráme, že modifikovaný výpočet normalizovaného alfa indexu je vhodný pro klinickou praxi.

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