HEART RATE VARIABILITY ANALYSIS

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ABSTRACT

The analysis of heart rate variability (HRV) is a rapidly developing branch of cardiology, in which the possibilities of computational methods are most fully realized. This direction was largely initiated by the pioneering work of the famous Russian researcher R.M. Baevsky [2] in the field of space medicine, who for the first time introduced into practice a number of complex indicators characterizing the functioning of various regulatory systems of the body.

Keywords: heart rate variability, ECG, signals, program, R-waves.

The heart is ideally able to respond to the slightest changes in the needs of numerous organs and systems. The variational analysis of the heart rhythm makes it possible to quantify and differentiate the degree of tension or tone of the sympathetic and parasympathetic divisions of the ANS, their interaction in various functional states, as well as the activity of subsystems that control the work of various organs. Therefore, the maximum program of this direction is to develop computational and analytical methods for complex diagnostics of the body according to the dynamics of the heart rhythm.

HRV methods are not intended for diagnosing clinical pathologies, where, as we have seen above, traditional means of visual and measuring analysis work well. The advantage of this section is the ability to detect the subtlest abnormalities in cardiac activity, so its methods are especially effective for assessing the general functionality of the body in the norm, as well as early deviations, which, in the absence of the necessary preventive procedures, can gradually develop into serious diseases. The HRV technique is also widely used in many independent practical applications, in particular, in Holter monitoring and in assessing the fitness of athletes, as well as in other professions associated with increased physical and psychological stress (see at the end of the section).

The starting material for HRV analysis is short single-channel ECG recordings (from two to several tens of minutes) performed in a calm, relaxed state or during functional tests. At the first stage, successive cardiointervals (CI) are calculated from such a record, R-waves are used as the reference (boundary) points of which, as the most pronounced and stable components of the ECG.

HRV analysis methods are usually grouped into the following four main sections:

- intervalography;
- variational pulsometry;
- spectral analysis;
- correlation rhythmography.

Other methods. To analyze HRV, a number of less commonly used methods are also used, related to the construction of three-dimensional scattergrams, differential histograms, the calculation of autocorrelation functions, triangulation interpolation, and the calculation of the St. George index [1]. In the evaluation and diagnostic plans, these methods can be characterized as scientific and exploratory, and they practically do not introduce fundamentally new information.

Holter monitoring. Long-term Holter ECG monitoring involves many hours or many days of single-channel continuous ECG recording of a patient in their normal living conditions. Recording is carried out by a portable portable recorder on a magnetic carrier. Due to the long time duration, the subsequent study of the ECG recording is carried out by computational methods. In this case, an intervalogram is usually built, areas of a sharp change in rhythm are determined, extrasystolic contractions and asystolic pauses are looked for, counting their total number and classifying extrasystoles according to shape and localization.

Intervalography

In this section, methods of visual analysis of graphs of changes in successive CIs (intervalogram or rhythmogram) are mainly used. This makes it possible to assess the severity of various rhythms (first of all, the respiratory rhythm, see Fig. 1) and to identify disturbances in the variability of CI, asystole and extrasystole. So in fig. Figure 5 shows an intervalogram with three heartbeat skips (three extended CIs on the right side) followed by an extrasystole (shortened CI) immediately followed by a fourth heartbeat skip.

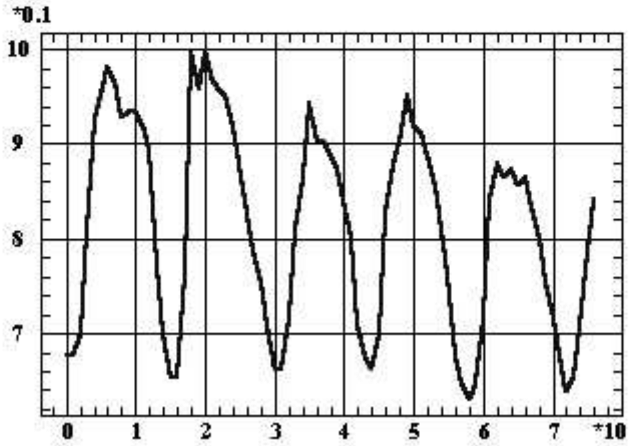


Fig. 1. Intervalogram of deep breathing

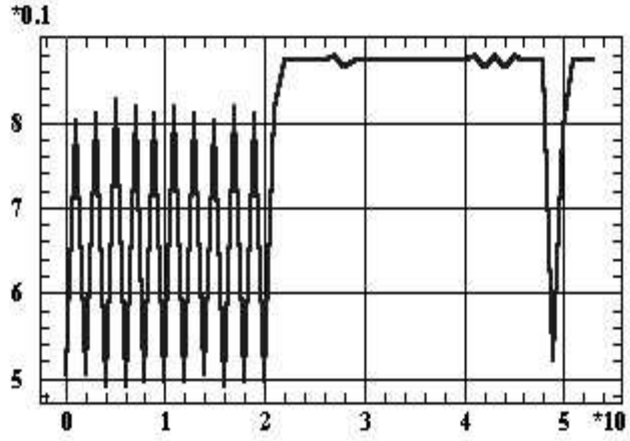


Fig. 2. Fibrillation intervalogram

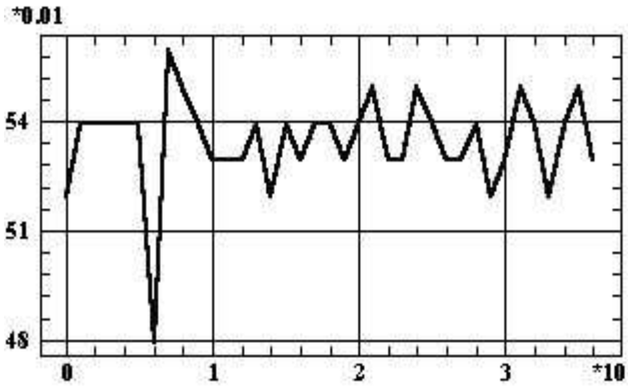


Fig. 3. Intervalogram of the prefibrillation state

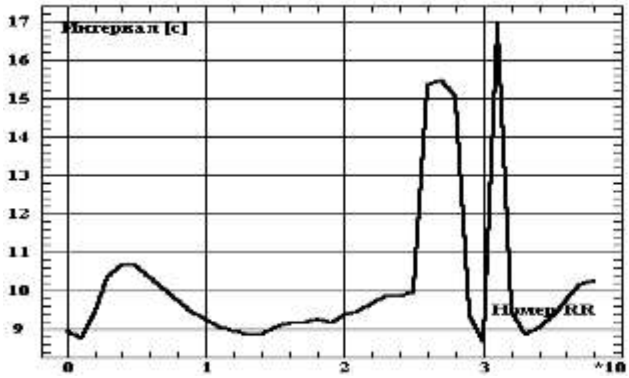


Fig.5. Intervalogram with skipping episodes

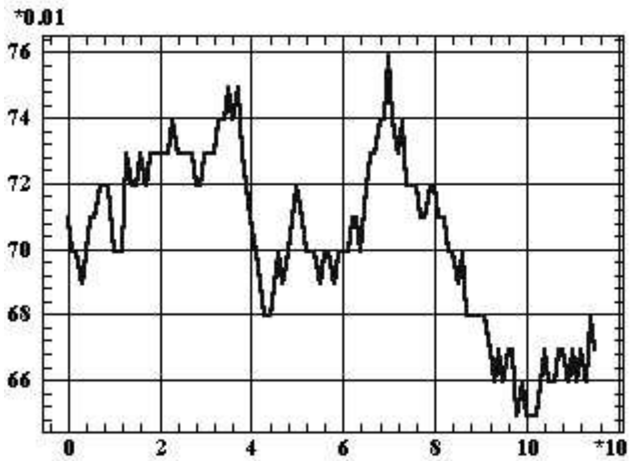
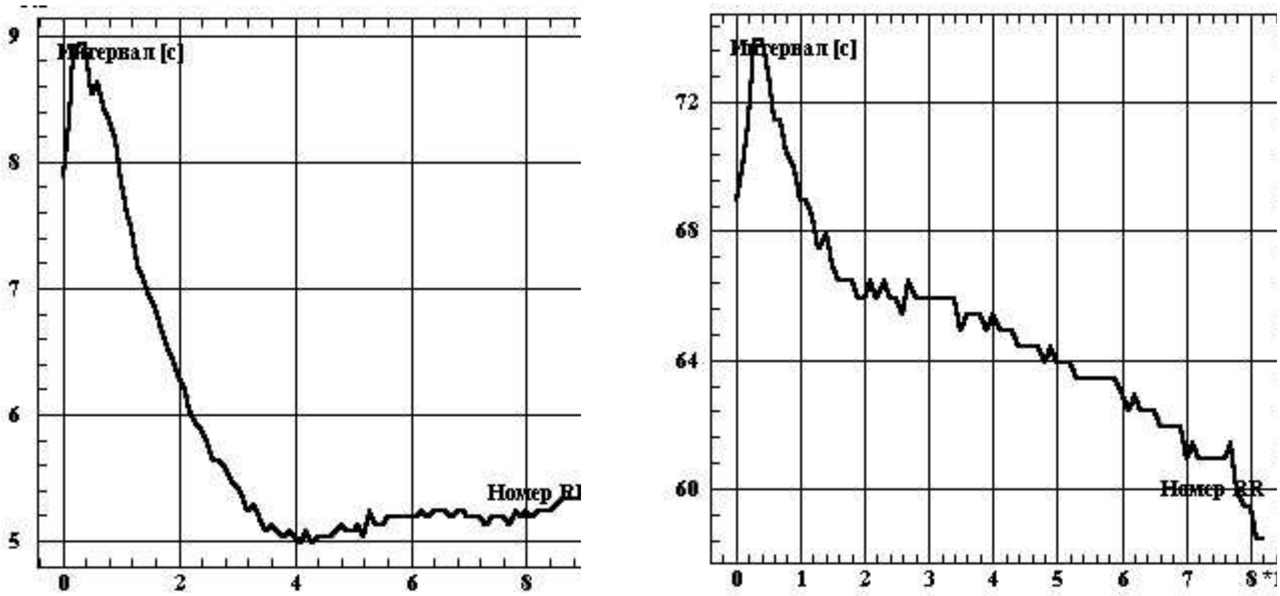


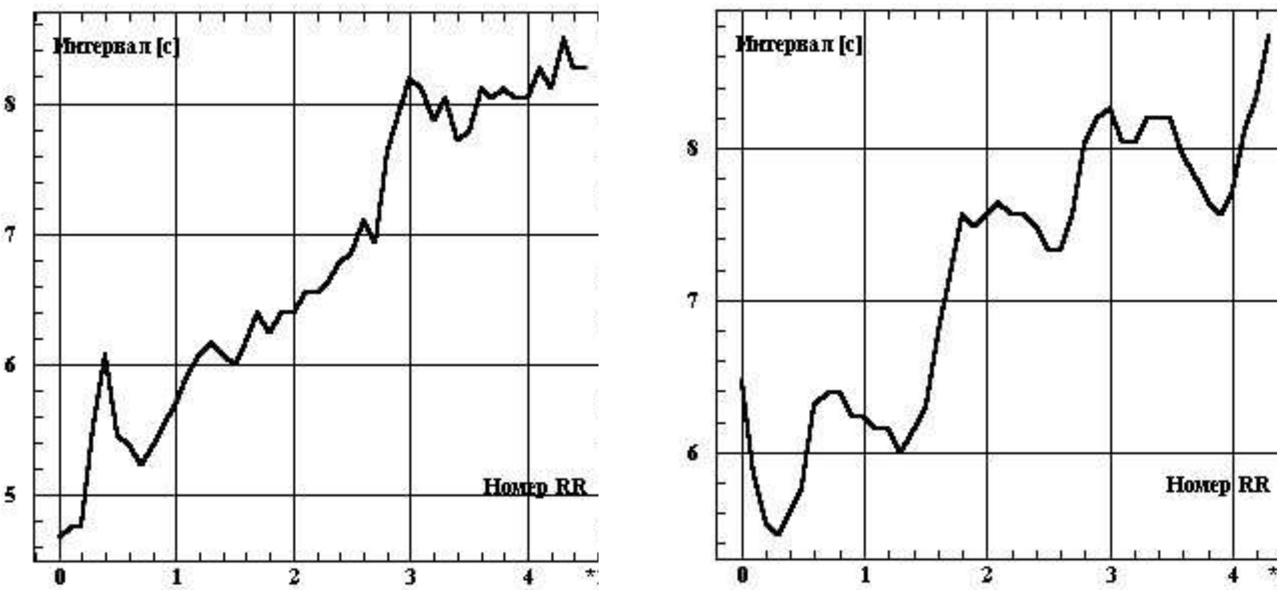
Fig. 4. Intervalogram of a patient with normal health, but with obvious violations in HRV

The intervalogram makes it possible to identify important individual features of the action of regulatory mechanisms in response to physiological tests. As an illustrative example, consider the opposite types of reactions to a breath holding test. Fig. 6 shows the reactions of heart rate acceleration during breath holding. However, in the subject (Fig. 6, a), after the initial sharp decline, stabilization occurs with a tendency to some lengthening of the CI, while in the subject (Fig. 6, b), the initial sharp decline continues with a slower shortening of the CI, while disturbances in variability appear. CI with a discrete nature of their alternation (which for this subject did not manifest itself in a state of relaxation). Figure 7 shows the reactions of the opposite nature with the lengthening of the CI. However, if for the subject (Fig. 7,



A) b)

Fig. 6. Intervalograms for breath holding tests with shortening K



a) b)

Fig. 7. Intervalograms for breath holding tests with CI lengthening

Variation pulsometry

In this section, descriptive statistics tools are mainly used to assess the distribution of CI with the construction of a histogram, as well as a number of derived indicators characterizing the functioning of various regulatory systems of the body, and special international indices. For many of these indices, on a large experimental material, the clinical limits of the norm were determined depending on gender and age, as well as a number of subsequent numerical intervals corresponding to dysfunctions of one degree or another.

Bar chart. Recall that a histogram is a graph of the probability density of a sample distribution. In this case, the height of a particular column expresses the percentage of cardiointervals of a given duration range present in the ECG record. For this, the horizontal scale of CI durations is divided into successive intervals of equal size (bins). For comparability of histograms, the international standard sets the bin size to 50 ms. Normal cardiac activity is characterized by a symmetrical, domed and solid histogram (Fig. 8). During relaxation with shallow breathing, the histogram narrows, and when breathing deepens, it widens. If there are gaps in contractions or extrasystoles, separate fragments appear on the histogram (respectively, to the right or left of the main peak, Fig. 9). The asymmetric shape of the histogram indicates the arrhythmic nature of the ECG. An example of such a histogram is shown in Fig. 10, a. To clarify the reasons for such asymmetry, it is useful to refer to the intervalogram (Fig. 11, b), which in this case shows that the asymmetry is determined not by pathological arrhythmia, but by the presence of several episodes of a change in normal rhythm, which can be caused by emotional reasons or changes in depth. and respiratory rate.

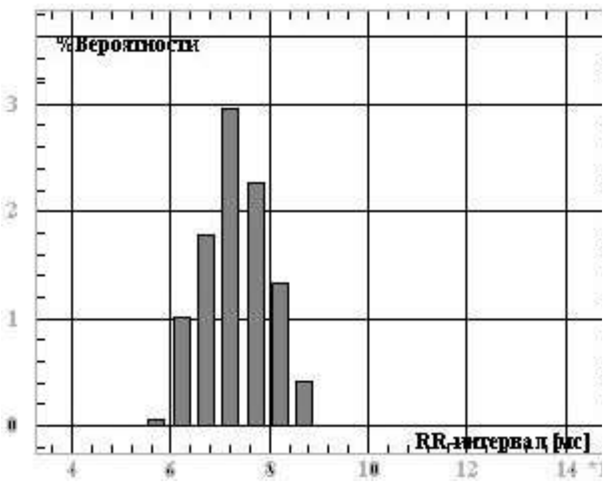


Fig. 8. Symmetrical histogram

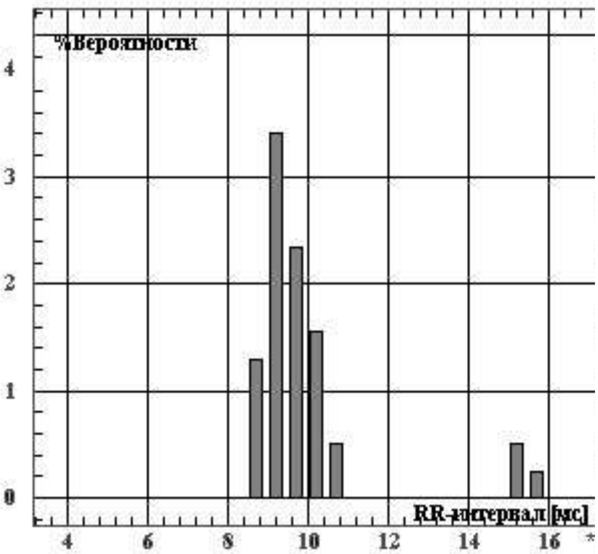
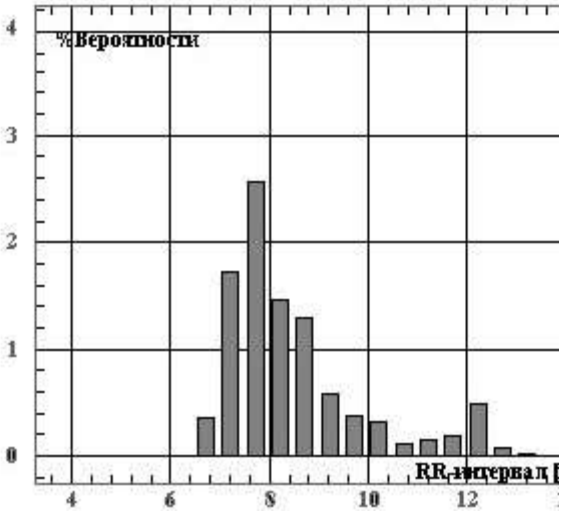
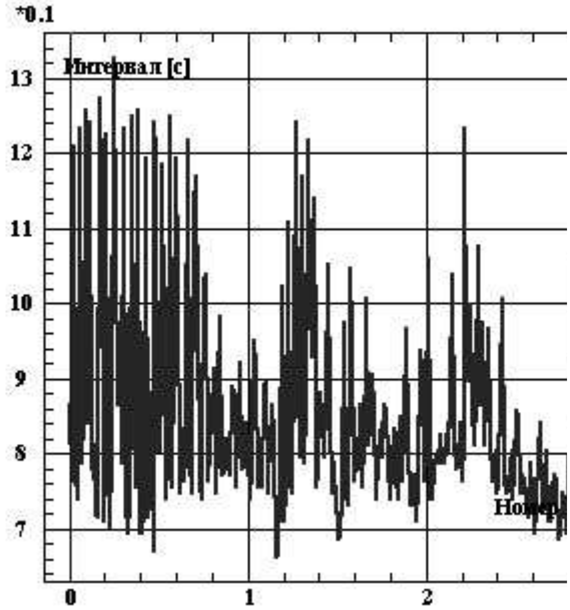


Fig. 9. Histogram with missing cuts



A)



b)

Fig. 10. ECG with episodes of rhythmic change:
a - histogram; b – intervalogram

Indicators. In addition to the histographic representation in variational pulsometry, a number of numerical estimates are also calculated: descriptive statistics, Baevsky's indicators, Kaplan's indices, and a number of others.

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