Methods and Devices

Variations in circulation may be evaluated by a number of methods including heart rate variability (HRV), variability of pulse, blood pressure, stroke volume, maximal volume and linear speed of the bloodstream in aorta and other vessels. Other periodic processes occurring in the cardiovascular system may also be analysed. In this part we are going to concentrate on HRV technology.

Methods of obtaining the HRV parameters may by divided into three main groups:

1. Time domain methods
2. Spectral domain methods
3. Non - linear methods
4. Mathematic modeling methods

1. Time Domain Methods

The basis of these methods is either the heart rate at any point in time or the intervals between successive complexes. In a continuous electrocardiographic (ECG) record each QRS complex is detected, and the so-called normal-to-normal (NN) intervals (i.e. intervals between adjacent QRS complexes resulting from sinus node depolarisation), or the instantaneous heart rate is determined.

Statistical Methods

The measures obtained after analyses of a series of instantaneous heart rates or NN intervals can be divided into 2 classes:

1. those derived from direct measurements of the instantaneous heart rate or NN intervals
2. those derived from the differences between NN intervals

The variables to be obtained are the following:

- Mean heart rate (**HR**, int/min)
- Mean NN interval (**mNN** or mRR, ms)
- Standard deviation of the NN interval (**sdNN** or **sdRR**, ms) - the square root of variance between the NN intervals.
  Since variance is mathematically equal to total power of spectral analysis, sdNN reflects all the cyclic components responsible for variability in the period of recording.
- Standard deviation of the average NN interval calculated over 5-min periods within the 24 - hours recording (**SDANN**, ms).
  This parameter is an estimate of the changes in heart rate due to cycles longer than 5 minutes
- Mean of the standard deviations of all NN intervals for all 5 min segments of entire recording (**SDNN** index, ms)
  This index reflects the variability due to cycles shorter than 5 minutes
- The square root of the mean squared differences of successive NN intervals (**RMSSD**, ms).
- The number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording (**NN50**)

- NN50 count divided by the total number of all NN intervals (**pNN50**, %)

The last three measurements reflect high frequency variations in the structure of HRV and thus are highly correlated.

Geometrical Methods

The series of NN intervals can also be converted into several geometric patterns:

- interval tachogram is a graph of the NN intervals complexes (Fig 1)

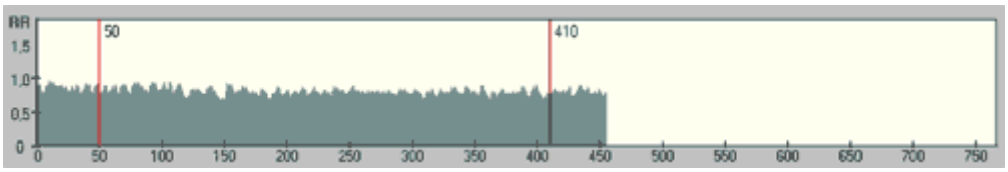

Fig. 1. Interval tachogram recorded by CardioLab 2000 device.

- Scaterogram looks like a "cloud" which consists of a number of points. Abscissa of the point is the length of the previous NN interval. Ordinate of the point it the length of the subsequent NN interval (Fig. 2). The decreased HRV is reflected in a greater density and smaller size of the cloud. The type of the point distribution is determined by origin of QRS complexes.

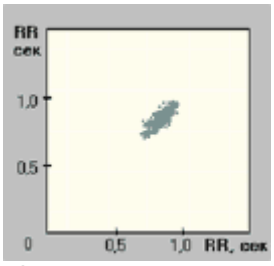

Fig. 2. Scaterogram recorded by **CardioLab 2000** device.

- The triangular index (HRVTi) is the integral of the density distribution divided by the maximum of the density distribution. The index reflects total heart rate variability measured over 24 hours and is more influenced by the lower than by the higher frequencies.

2. Spectral Domain Methods

Methods for calculation of power spectral density may be classified as parametric and non-parametric; in most instances both methods provide comparable results. The important characteristics of the spectrum are the power of the spectrum and the powers of its separate zones. Four main spectral components are distinguished.

Analysis of the short-term recordings (5 min)

- **Total Power** ms^2 - Variance of all NN intervals (Fig. 3)
- **VLF**, ms^2 - power in the very low frequency range (0,003-0,04)
- **LF**, ms^2 - power in the low frequency (0,04 - 0,15 Hz)
- **LFnorm**, n.u. - LF power in normalized units: LF/(Total Power - VLF)*100
- **HF**, ms^2 - power in the high frequency range (0,15 - 0,4 Hz)
- **HFnorm**, n.u. - HF power in normalized units: HF/(Total Power - VLF)*100
- **LF/HF** - ratio LF[ms^2]/HF[ms^2]

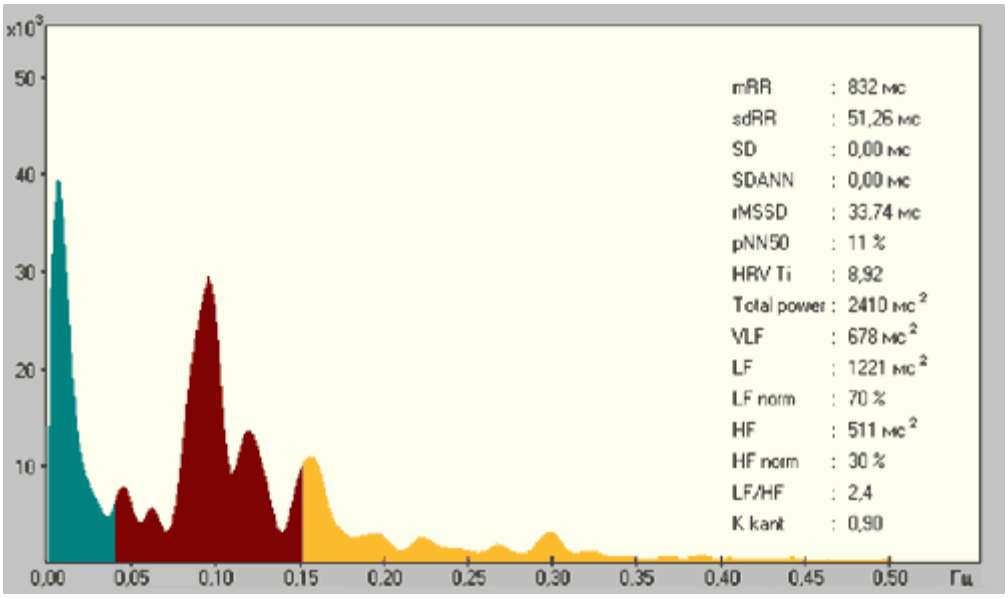

Fig. 3 Example of power spectral density obtained from 5-min recording. Blue zone reflects power of spectrum of RR interval in VLF range, red zone corresponds LF power and the yellow zone stands for HF power.

Analysis of the long - term recording (24 hours)

- **Total Power** ms^2 - Variance of all NN intervals
- **ULF**, ms^2 - power in the ultra low frequency range (<0,003 Hz)
- **VLF**, ms^2 - power in the very low frequency range (0,003 - 0,04 Hz)
- **LF**, ms^2 - power in the low frequency (0,04 - 0,15 Hz)
- **HF**, ms^2 - power in the high frequency range (0,15 - 0,4 Hz)
- a - slope of the linear interpolation of the spectrum in a log-log scale

The physiological role of the different heart spectrum components is under the study now. Nevertheless some correspondence is already known. The power of spectrum in ULF range is analysed in twenty-four-hour ECG recordings. The origin of this zone is unknown, however the prognosis of a sudden death according to its power is the most accurate. The physiological correlations of the VLF zone power are still unsettled. It is thought to be connected with thermoregulation, the renin-angiotensin system activation and with changes in physical activity. The LF range power is to some extent generated by baroreceptor modulations of sympathetic and vagus nervous tone. According to other references it is mostly dependent on the sympathetic activation. The power in the HF zone is generated by respirator modulation of the vagus nerve activity.

3. Non - Linear Methods

The stochastic indexes of the regulatory systems functioning may be obtained by chaos analyses of the heart rate variability. Such indexes are thought to reflect the stress resistance of regulatory systems.

4. Mathematic Modeling Methods

Mathematic modeling is a special tool that gives the possibility to evaluate those properties of regulatory systems and processes that can't be obtained by direct measures. Sensitiveness and specificity of the effective systems to humoral sympathetic and parasympathetic influences can be obtained with the help of these methods.

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