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The Graphical Analysis of the Heart Rate Variability

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Main terms used

ECG – a recording of the cardiac-induced skin potentials at the body's surface;

HRV – called heart rate variability, the variability of the RR-interval sequence;

RR interval – interval between successive Rs where R is the point corresponding to the peak of the QRS complex of the ECG wave;

NN interval – interval between adjacent QRS complexes resulting from sinus node depolarization;

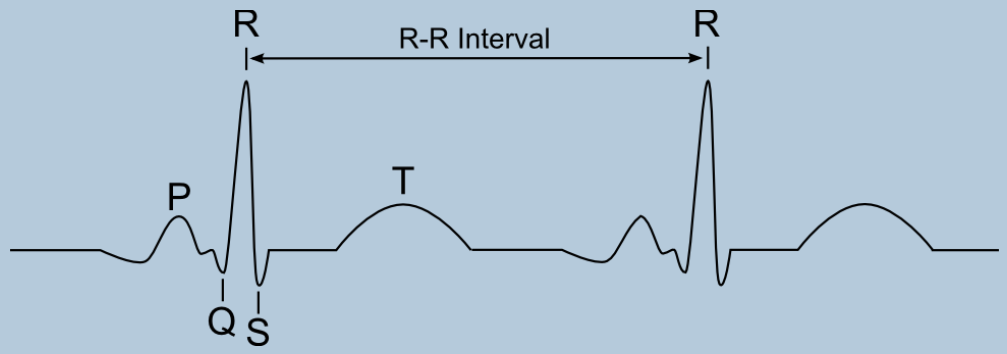
PNS, SNS – parasympathetic and sympathetic nervous system respectively;

SIDS – sudden infant death syndrome.

What is HRV?

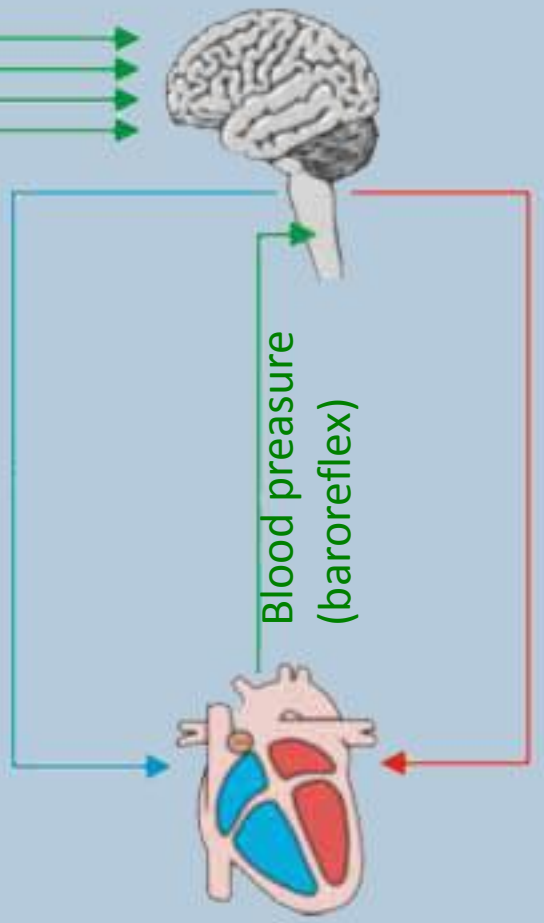
Heart rate variability (HRV) is a physiological phenomenon where the time interval between heart beats varies. It is measured by the variation in the beat-to-beat interval.

Other terms used include: "**cycle length variability**", "**RR variability**" and "**heart period variability**".



Physiological aspects

Respiration
Cardiac Output
Humoral Factors (RAS)
Thermoregulation



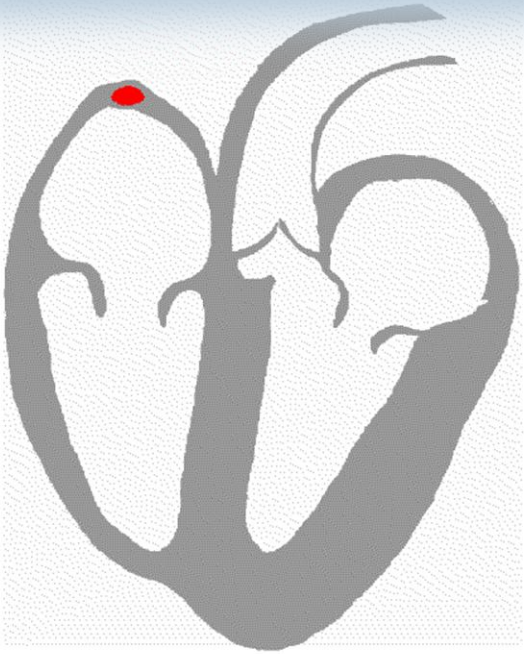
Parasympathetic NS
(N. Vagus)

Fast Response – 1-2 heartbeats
Higher Frequency Modulation

Sympathetic NS
(Paravertebral Ganglia)

Slow Response – Over 5 sec
Lower Frequency Modulftion

Clinical significance



Reduced HRV has been shown to be a predictor of mortality after myocardial infarction although others have shown that the information in HRV relevant to acute myocardial infarction survival is fully contained in the mean heart rate.

A range of other outcomes/conditions may also be associated with modified (usually lower) HRV, including:

- congestive heart failure,
- diabetic neuropathy,
- depression post-cardiac transplant,
- susceptibility to SIDS,
- poor survival in premature babies.

Methods

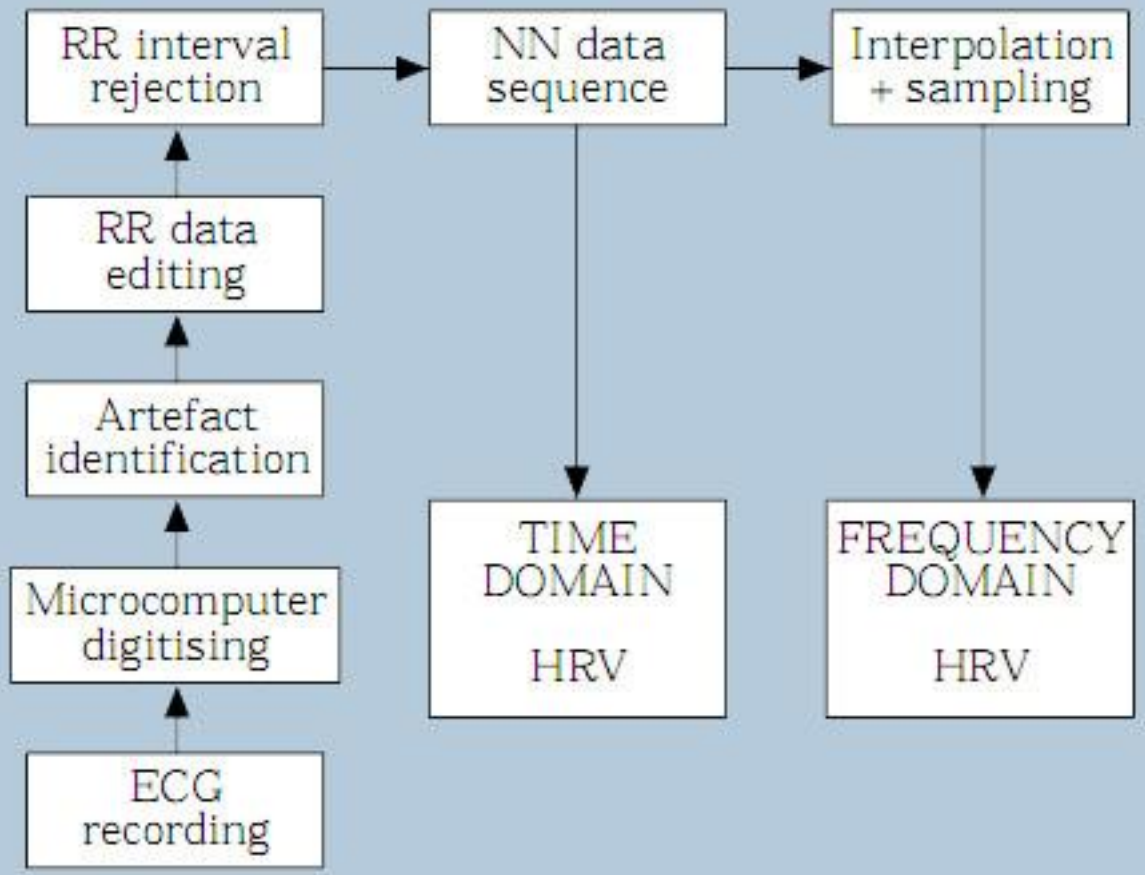
Time-domain methods

- Statistical methods
- Geometrical methods

Frequency-domain methods

- Short-term recordings
  Spectral analysis
- Long-term recordings
  Spectral analysis

Software structure



Signal preprocessing

- Preliminary signal filtration by the means of high-pass and low-pass filters:

  a) 2-nd order *Butterworth* high-pass filter with the cut-off frequency 0.5 Hz
  b) low-pass filter – the simple 6-order “rectangular widow” with the cut-off frequency in 30 Hz.

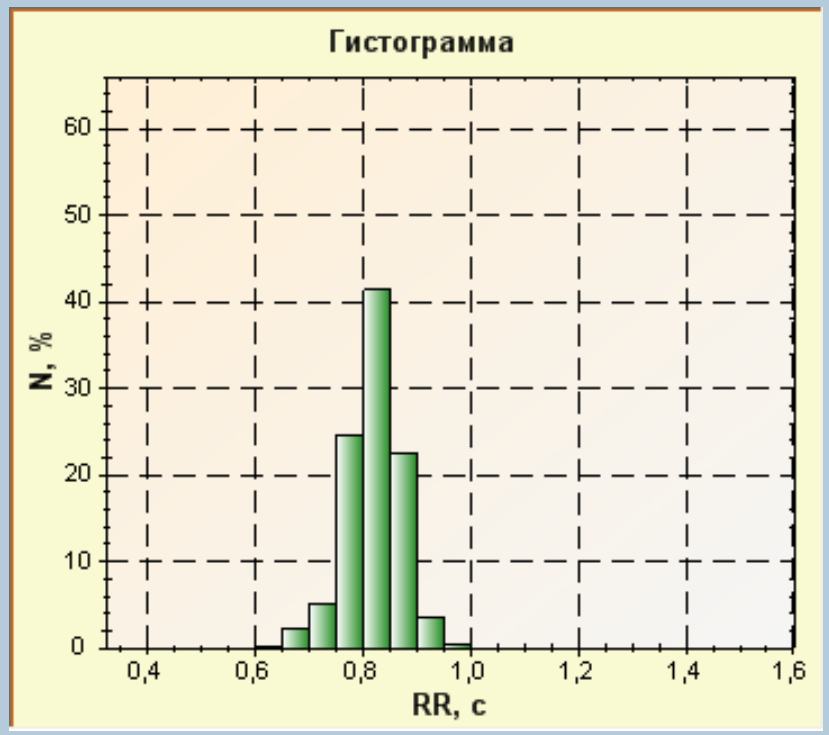
- QRS-complexes identification by the method that is based on the Pan- Tompkin’s algorithm; this includes stages of differentiation, squaring, integration and at last, adaptive threshold R-peak scanning procedure;

- contour signal analysis that provides identification of the key ECG-cycle points.

Statistical analysis

The direct data analysis by group of the time-domain methods:

- cardiointervalogram forming and plotting;
- graphical and statistical processing of the RR-sequence with histogram plotting and analysis;
- scattergram plotting and graphical approximation of the RR—distribution cloud with the ellipse figure and approximation parameters post-calculation.



Statistical processing

HR, per min – heart rate;

SDNN, ms – standard deviation of all NN intervals;

RMSSD, ms – the square root of mean of the sum of the squares of differences between adjacent NN intervals;

CV , % – variation coefficient;

pNN50, % – NN50 count divided by the total number of all NN intervals;

MxDMn, ms – range of deviation;

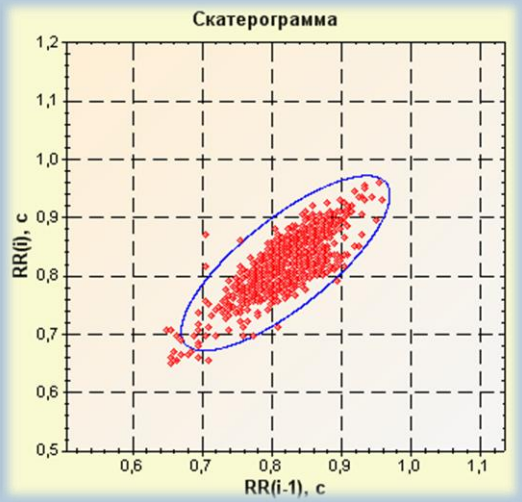
Mo, ms – mode;

AMo, % – mode amplitude;

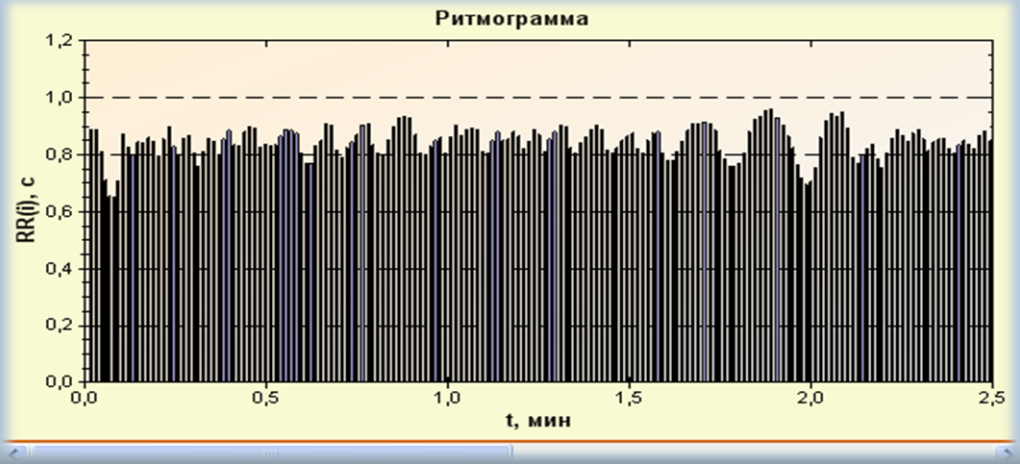
SI – stress index

	Значение	Норма
HR, уд/мин	73	55 - 80
SDNN, мс	50	30 - 100
RMSSD, мс	33,1	20 - 50
CV, %	6,1	3 - 12
pNN50, %	51,6	
MxDMn, мс	350	
Mo, мс	825	
AMo, %	41,4	30 - 50
SI, усл.ед.	72	50 - 150

Geometrical analysis



Scattergram (Poincare Plot) is a commonly-used method to visually assess heart rate variability as a function of RRIs. In this plot, each RRI is plotted against the RRI of the next subsequent beat.



Pulsogram is the RRI plot where the value of each RRI (in seconds) is represented for each beat. It's basically the inverse of heart rate. Miscalculated heartbeats would show up as extremely high or extremely low dots on this graph.

Approximation outputs

L, sec – length of the main cloud (excluding extrasystoles and artifacts) – long ellipse axis;

W, sec – scattergram width – perpendicular to the long ellipse axis, traced through its center – short ellipse axis;

α, degree – angulation of the main axis;

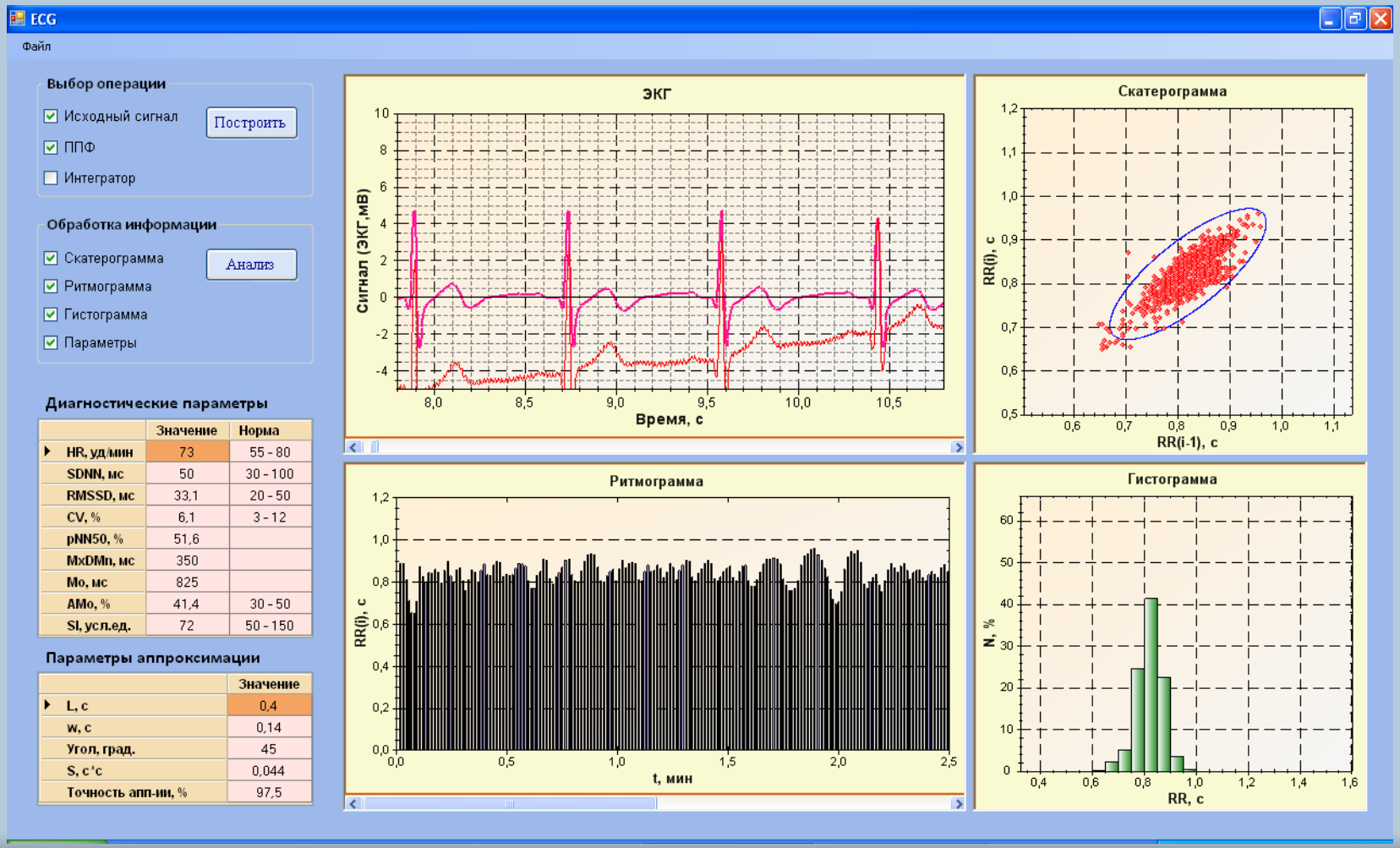
S, sec^2 – scattergram area, that's calculated as:

$$S=(\pi*L*w)/4;$$

Percentage of the approximation – number of points that were included inside the ellipse related to the total point number.

	Значение
L, c	0,4
w, c	0,14
Угол, град.	45
S, c*c	0,044
Точность апп-ии, %	97,5

Software interface



Resumes and Perspectives

There are still enough work in field of HRV analysis, especially in the questions of automation, including normal and pathological ranges of diagnostic parameters research.

Apart from the need to develop numerically robust techniques suitable for fully automatic measurement (the geometric methods are only one possibility in this direction), the following three areas deserve attention:

- **Dynamics and Transient Changes of HRV**
- **PP and PR Intervals**
- **Multisignal Analysis**

Thank you for attention!