HRV Parameters and levels of risk

- **Statistical characteristics**
- The statistical characteristics of a dynamic number of cardio intervals include: Heart Rate (HR), Average Square Deviation (Standard Deviation Normal to Normal-SDNN), Coefficient of Variation (CV). Except these "classical" statistical parameters there are calculated another four different parameters: SDSD, RMSSD, NN50, pNN50. A new dynamic line of numerical values of differences between each previous and subsequent cardio intervals is for this purpose formed. Receiving line of values differences, it is possible to distinguish constant making of a dynamic line and all slow fluctuations. There is only the fast component of variability (only respiratory fluctuations of cardio intervals). Therefore, all different parameters in this or that measuring reflect activity of parasympathetic part of autonomous nervous system, i.e. concern to independent contour of management .SDSD - the average square-law deviation of dynamic line of different values, RMSSD - the square root of sum of squares of different values (Root Mean of Sum Successive Deviations); NN50 - the number of different value above 50 milliseconds, pNN50 - the same parameter, but in % from common number of analyzed intervals.

Variational pulsometry

The essence of variational pulsometry consists of study of the law of distribution of cardio intervals as of casual sizes. A curve of distribution - histogram is for this purpose is constructed. The method “variational pulsometry” corresponds to geometrical methods of European-American standards. On fig. 4b a typical curve of distribution with main mathematical parameters designated on is submitted: Mo (Mode), AMo (Amplitude of a Mode), MxDMn (variation scope = Difference between Maximal and Minimal value). Medical and physiological interpretation of the specified parameters is below given in brief.

Mode - the most value frequently observed in the dynamic line of cardio intervals. In physiological sense - this is the most probable level of cardiovascular functioning. By normal distribution and high stationarity of researched process, Mo poorly differs from M (mathematical expectation), i.e. from average value. The distinction between Mo and M means worsened stationarity (of researched process) and shows (most probably) presence of transients (more significantly).

The amplitude of a mode (AMo) is number of cardio intervals appropriate to Mo value, in %. This parameter characterizes similarity of values of cardio intervals and reflects stabilizing effect of heart rhythm management, which is caused, basically, by degree of sympathetic system activation.

The variation scope (MxDMn) reflects a degree of variability of cardio intervals values in researched dynamic line. It is calculated as difference of maximum and minimum values of cardio intervals and consequently at arrhythmias or artifact errors, what can be allowed, if the dynamic line of cardio intervals was not subject to preliminary editing. At calculation of MxDMn, usually, the extreme values of cardio intervals are rejected, if they make less than 3 percents from full amount of analyzed sample. Physiological sense of MxDMn is usually connected to activity of parasympathetic system. However, in number of cases, the significant amplitude of slow waves making value MxDMn (by long lasting records) can reflect a condition of activity of sub cortical nervous centers.

- On data of variational pulsometry the number of derivative parameters is calculated, among which index of regulatory systems tension (Stress Index - SI) is the most common, which reflects a degree of centralization of heart rhythm management and characterizes, basically, activity of the sympathetic part of autonomic nervous system. It is calculated by following formula:
- SI = AMo / 2Mo * MxDMn
- This parameter has received wide application in sport medicine, physiology of labor, space research, and in clinical practice, too. The value of SI is normally in limits from 50 up to 150 conditional units (c.u.). At emotional load and physical work by healthy people, SI value is increased up to 300 - 500 c.u., and by people of the senior age (with reduced reserves) such values are observed even in rest. At presence of coronary heart disease, the SI reaches 600-700 c.u., and in pre-infarction state even 900-1100 c.u.

Correlation rhythmography (CRG)

This method of graphic representation of a dynamic line of cardio intervals in kind of "cloud" (scatter gram) by construction of a number of points in rectangular system of coordinates. Thus, on axis of ordinates is postponed - each current R-R an interval, and on axis abscissa - each subsequent R-R an interval. On fig. 4c a typical sample CRG is submitted. Important advantage of this method is the fact that it permits effectively to distinguish and to analyze the cardiac arrhythmias. Numerical parameters CRG are in axes of ellipsis (“a” and “b”), formed by a cloud of points and their relation a/b. The physiological sense of the relation a/b is close to SI - it characterizes a degree of centralization of heart rhythm management, activity of sympathetic part of autonomous nervous system.

Autocorrelation analysis

Calculation and the construction of autocorrelation function of a dynamic line of cardio intervals (see fig 4b) is directed on study of internal structure of this line as a causal process. The autocorrelation function represents the diagram of dynamics of coefficient of correlation, received at consecutive displacement of an analyzed dynamic line on one number in relation to own line. After first shift of one value, when coefficient of correlation is less than one, than the respiratory waves are more expressed. When in researched sample dominate slow waves components, the coefficient of correlation after first shift will be only a little bit shorter than one. The subsequent shifts conduct to gradual reduction of coefficient of correlation down to occurrence of negative coefficient of correlation. The physiological sense of use of the autocorrelation analysis consists of estimation of a degree of influence of the central contour of management on independent contour. If this influence is increased, then closer to one the value of coefficient of correlation and first shift is close to one. Autocorrelogram permits to judge latent periodicity of heart rhythm. However, such analysis has only qualitative character.

Spectral analysis

For exact quantitative estimation of periodic processes in heart rhythm serves spectral analysis. The physiological sense of the spectral analysis is in possibility to estimate activities of different (separate) levels of regulatory systems. On fig.4d a sample of a typical HRV spectrum for sample of volume in 5 minutes is submitted. Here on axis abscissa values of periods of fluctuations in seconds are postponed, on axis ordinates capacities of appropriate spectral making in square milliseconds (ms2) are postponed. At spectral analysis of so-called short dynamic lines of cardio intervals (duration up to 5 minutes) it is possible to measure only capacities of respiratory waves and slow waves of 1st and 2nd order. As to slow waves of 2nd order, under European-American standards their range is determined in limits from 0,04 up to 0,003 Hz (or from 25 up to 300 s). However, the numerous literary data testify that in specified range fluctuations of a various nature are observed: connection with processes of thermoregulation (Sayers, 1973, 1981), by oxy-recovery processes, with metabolic processes, in particular with glycolysis (Boiteux et al, 1977). Thus, in range up to 300 s, it is possible to allocate waves not only 2nd, but also 3rd – 4th of the orders.

Therefore, in the KARDiVAR system slow waves of 2nd order are calculated in interval from 25 to 66 seconds (0,04-0,015 Hz). As a rule, these waves are associated with activity of suprasegmental part of a brain (Haspekova, 1994), with activity of sympathetic sub cortical centers. As to slow waves 3rd – 4th of the orders, their main capacity is reflected, as a rule, in the 1st harmonic of spectrum. The names of spectral components, according to European-American standards are accepted. Their names reflect frequent structure: high-frequency fluctuations (High Frequency -HF), low-frequency fluctuations (Low Frequency -LF), very low-frequency fluctuations - (Very Low Frequency -VLF), and ultra-low-frequency fluctuations (Ultra Low Frequency - ULF). The frequent ranges of the specified components are submitted in table:

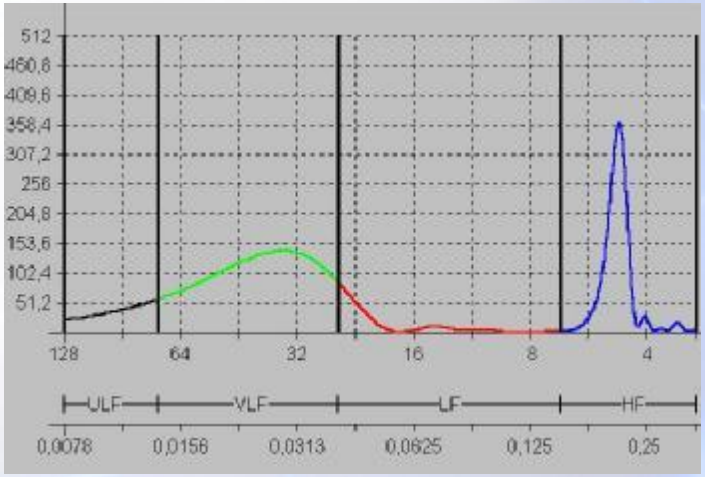
Components of a spectrum	Frequency range in Hz	Period in seconds
HF	0,4 – 0,15	2,5 – 7
LF	0,15 – 0,04	7 – 25
VLF	0,04 – 0,015	25 – 66
ULF	Less than 0,015	More than 66

At spectral analysis it is usual for each of components calculate absolute total power in own range, average power in every range, value of a maximum harmonic and relative value in percentage of total power in all ranges (Total Power-TP). It is necessary to note distinctions in an estimation of spectral HRV components between the Russian and European-American recommendations. In the last, the ratio HF/ LF is considered basically. Parameter HF/LF is interpreted as a parameter of vegetative balance

On data of the spectral analysis of HRV, the following parameters are calculated: Index of Centralization -IC (Index of centralization, IC = (VLF +LF / HF) and index of activation of sub cortical nervous centers ISCA (Index of Subcortical Centers Activity, ISCA = VLF / LF). IC reflects a degree of prevalence of non-respiratory sinus arrhythmia over the respiratory one. Actually - this is quantitative characteristic of ratio between central and independent contours of heart rhythm regulation. The second index ISCA characterizes activity of cardiovascular subcortical nervous center in relation to higher levels of management. The increased activity of sub cortical nervous centers is played by growth of ISCA. With help of this index processes the brain inhibiting effect can be supervised. Moreover, according to European-American standards the relation LF/HF is calculated. At calculation of relative values of separate spectral components of total spectral power (TP) into which enter HF, LF and VLF. is accepted to 100%. Value ULF is examined separately as this parameter reflects basically activity supersegmental levels of regulation and by present time still more not enough.

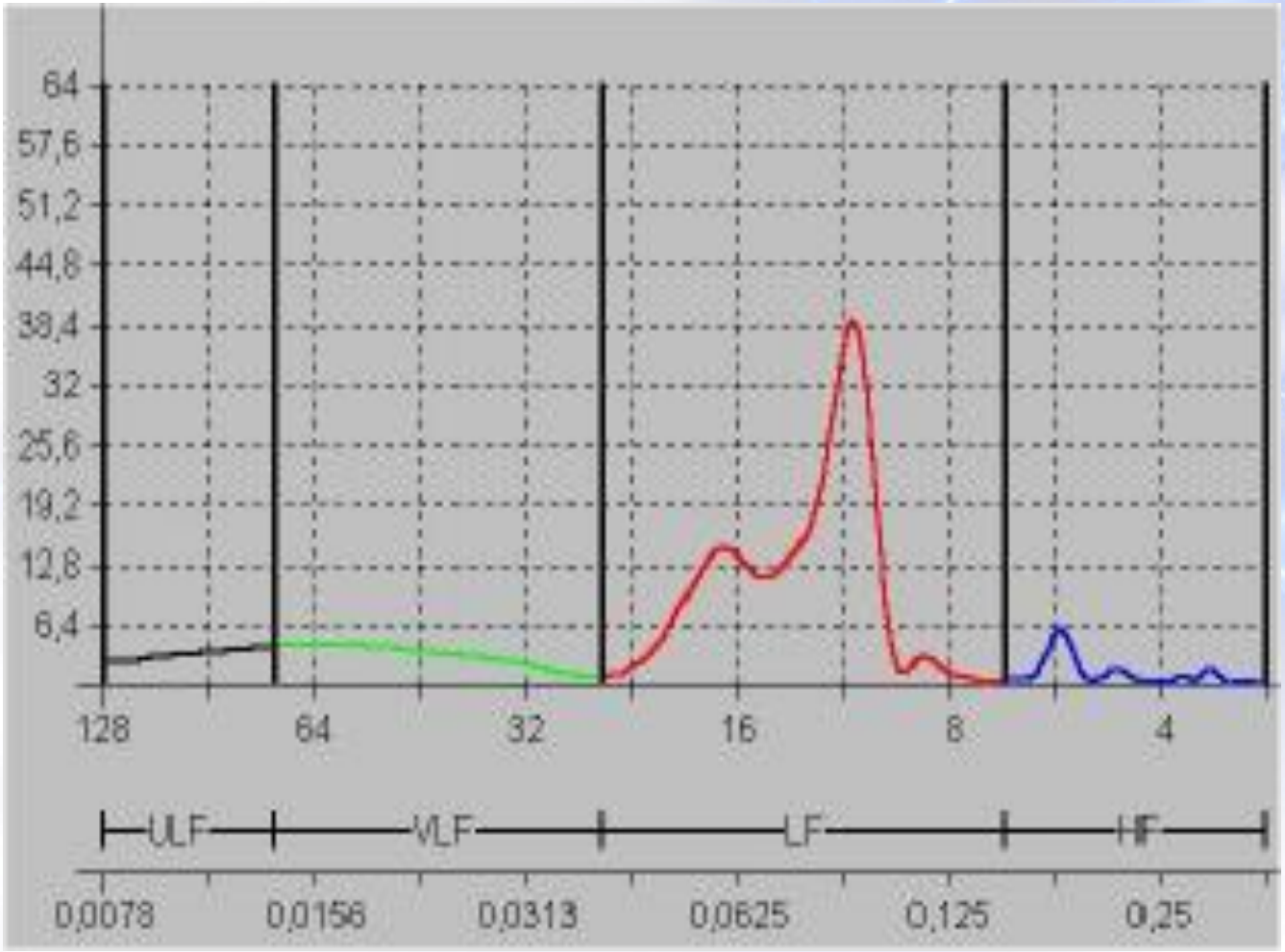
. **HIGH-FREQUENCY POWER OF HRV SPECTRUM** (Respiratory Waves). The activity of parasympathetic (vagal) part of autonomic nervous system, as one of components of autonomic balance, can be estimated by degree of suppression of activity of an independent contour of regulation, which is represented by spectrum in absolute and percentage kind. Usually respiration waves (HF-high frequency) make 15-25 % of total power of a HRV spectrum. Decrease of this part up to 8-10 % specifies displacement of autonomic balance to sympathetic prevalence.

If the value of HF falls below than 2-3 % it is possible to speak about sharp sympathetic prevalence. In this case, the parameters RMSSD and pNN50 also decrease. On the contrary, the increase part of respiration waves in HRV spectrum testifies the amplification of parasympathetic tone. The similar case is demonstrated in the diagram of a spectrum on fig. 6.

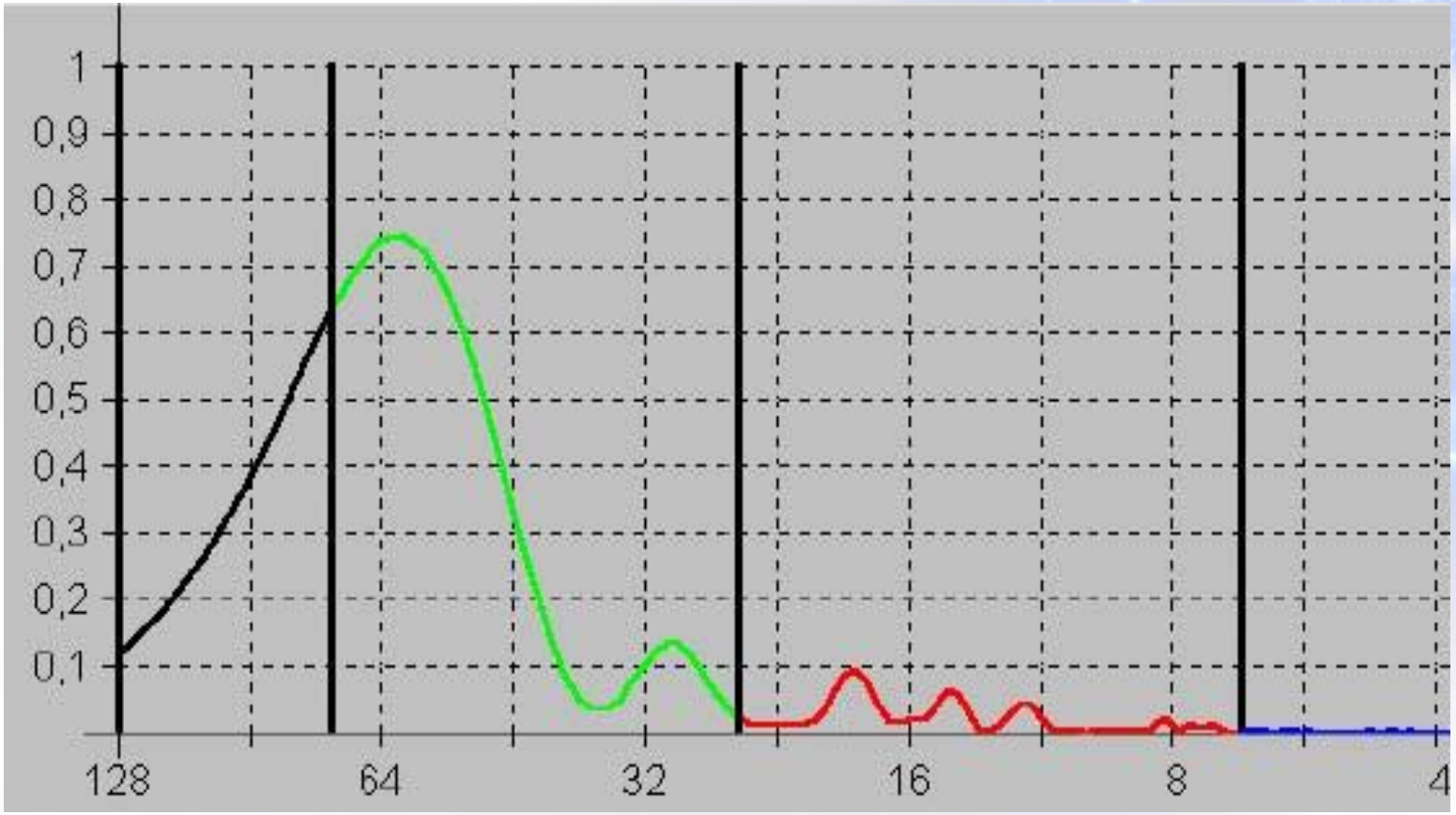

512
460,8
409,6
358,4
307,2
256
204,8
153,6
102,4
51,2
128
64
32
16
8
4
ULF
VLF
LF
HF
0,0078
0,0156
0,0313
0,0625
0,125
0,25

LOW FREQUENCY POWER OF HRV SPECTRUM (Slow waves of 1st order or vasomotoric or Mayer waves). This parameter (LF-Low Frequency) characterizes a state of vascular tone regulation system. In norm, sensitive receptors of sinocarotide zone detect the changes of values of blood pressure; perceive afferent nervous impulses acting in vascular sub cortical center. Here are carried out the afferent synthesis (processing and analysis of the acting information) and then the vascular system signals of management act. This process of the vascular tone control with feedback on musclefibres of vessels is carried out by vasomotoric center constantly. The time, necessary for vasomotoric center on operation after reception, processing and transfer of the information, varies from 7 to 20 seconds; on the average it is equal to 10 seconds. Therefore, in the heart rhythm there is possible to find out waves with frequency close to 0,1 Hz, which have received the name of vasomotoric waves.

These waves were observed by Maer (at first time) with co-authors (1931), and consequently they sometimes refer to as by Maer waves. The power of slow waves of 1st order determines activity of vasomotoric center. Transition from position “laying” (supine) to position “standing” (upright) usually conducts to substantial growth of power in this range of heart rhythm fluctuations. The activity of vasomotoric center falls with age and at persons of elderly age this effect is practically not present. Instead of slow waves of 1st order, power of slow waves 2nd order is increased. It means that the regulatory process of blood pressure control is carried out by participation of nonspecific gears, by activation of sympathetic part of autonomic nervous system. Usually in norm, percentage of vasomotoric waves in supine position makes from 15 up to 35-40 %. The substantial growth of vasomotoric waves power (see fig.7). Recognition of amplification of sub cortical vascular center can be caused currently by reactions of vessels (for example, of psycho-emotional character), propensity to hypertension, and raised sensitivity of vascular center to various stress factors (vascular dystony). Follows to mention also the parameter of dominant frequency in range of vasomotoric waves: usually it is within the limits of 10-12 seconds. Increase to 13-14 seconds can specify delay of processing of the information in vasomotoric center or in delay of transfer of the information to system of baroreflex regulation.


64
57,6
51,2
44,8
38,4
32
25,6
19,2
12,8
6,4
128
64
32
16
8
4
ULF
VLF
LF
HF
0,0078
0,0156
0,0313
0,0625
0,125
0,25

VERY LOW FREQUENCY POWER OF HRV SPECTRUM (Slow Waves of 2nd order). Spectral making heart rhythm in range 0,04-0,015 Hz (25-70 s) in opinion of many foreign authors (Pagani M., 1989, 1994, Maliani, 1991) characterizes sympathetic activity. However, this is simplified interpretation of this parameter. In this case we should speak about more complex influences from parts of suprasegmental(VLF).levels of management, as the amplitude VLF is closely connected with psycho-emotional tension (Kudrjavtseva, 1974). Data of N.B. Chaspekova (1996) have authentically shown that VLF reflects cerebral ergo tropic influence on lower levels of management and permits to judge functional state of a brain at psychogenic and organic pathology of a brain. On data of A.N. Fleischman, VLF is very good indicator of management of metabolic processes (1996). Thus, VLF characterizes influence of highest autonomic centers on cardiovascular sub cortical center and can be used as a reliable marker of a degree of connection of independent (segmental) regulation levels of cardiovascular regulation with suprasegmental, including that of pituitary-hypothalamic and level of brain. In norm power of VLF makes 15-30 % of total power of a HRV spectrum. At amplification of sympathetic activity, caused by influences high autonomic centers the values of this parameter can reach 60-70 % (see fig. 8).


1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
128
64
32
16
8
4