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A HEART RATE VARIATIONS IN MYOCARDIAL INFARCTION PATIENTS: A POSSIBLE RELAXATION OSCILLATION LIKE TYPE AS A REFLECTION OF AN AUTONOMIC PARASYMPATHETIC FUNCTIONING IN STRESS CONDITIONS

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The complex of indices proposed for the analysis of ECG RR-intervalograms evaluates a degree activity for the parasympathetic as well as for the sympathetic nervous system. The analysis of the characteristics for σ_{15}-index belonging to this complex with the MI patients (in acute period) has shown that there is a possibility for functioning of the parasympathetic nervous system by the relaxation oscillation mode. Three variants of this mode were found with the MI patients. The variants correspond to the following biosystems: a) a steady one keeping the activity but with a low adaptation (observed when the disease is manifested favourably); b) an adaptive one but with a low activity reserve (correlates with serious hemodynamic disorders); c) an intermediate one located between the first and the second system with a transition process in progress, probably with self-sustained oscillations, the fact that once again enphasizes the severity of the patients state and clinically is associated with the frequent electric instability of myocardium.

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1. INTRODUCTION

Recent publications [1–5] have shown a high informability of a new method for analysing the parameters of the heart sinus rhythm (SR). This method allows for obtaining the data on the complex of statistical characteristics of SR (SCSR). It was found that the SCSR-complex is very important for evaluation of the patients with acute myocardial infarction (MI).

The analysis for the series of the successive intervals between heart beats (RR-intervals of electrocardiogram (ECG) forms the basis for this method (see Fig. 1.1). This series is designated as a RR-intervalogram. Graphically it is presented as a series successive vertical bars with the height corresponding to the values of RR-intervals (see Fig. 1.2). The envelope of the RR-intervalogram is known as rhythmogram (dotted line on Fig. 1.2). It should be specially noted that an important condition for this analysis is to study the heart regular synus rhythm only (recordings with arrhythmic compexes are excluded).

The given complex includes 6 indices of SCSR gained when analysing the rhythmogram comprising 300 RR-intervals.

Two of them are calculated with consideration for all 300 RR-intervals of the initial rhythmogram.

1. RR_{mean}/σ — ratio of an arithmetic mean value of RR-intervals (RR_{mean}) to their mean square deviation (standard de-

viation (SD)) designated as σ (sigma). According to the authors' opinion this ratio is an index of the heart rhythm variability independent of the rhythm frequency.

2. σ_{ds} (sigma of difference series) — is an index describing the spread of increments of successive RR-intervals (ΔRR_i) in relation to the mean increment (ΔRR_{mean}) for whole recording period. This index is calculated by the following formula:

$$\sigma_{ds} = \sqrt{\sum(\Delta RR_i - \Delta RR_{mean})^2/(N-1)},$$

where ΔRR_i is a value for a difference of each two successive RR-interval in the rhythmogram with number i ($1 \leq i \leq N$), including N elements.

The following 4 indices were determined for successive segments including I5 RR-intervals each; these successive segments enter into the initial rhythmogram formed by 300 cardiointervals. A value of a SD designated as σ_{15} was calculated for each group of 15 RR-intervals. Value 15 was chosen in accordance with the data on the time interval of the central neural regulation of SR [7]. The authors think that this allows for estimating the changes of SR in the time interval of 9–15 s. Index σ_{15} is calculated by the formula:

$$\sigma_{15} = \sqrt{\sum_{i=j+1}^{n+1}(RR_i - RR_{mean})^2/(n-1)},$$

where n — number of RR-intervals ($n = 15$), i, j — number of RR-intervals in their investigated series of 15 and 300 elements.

3. σ_{15}min — is an index equal to the least value of a SD σ_{15} for a series of successive segments each having 15 RR-intervals entering into the initial rhythmogram.

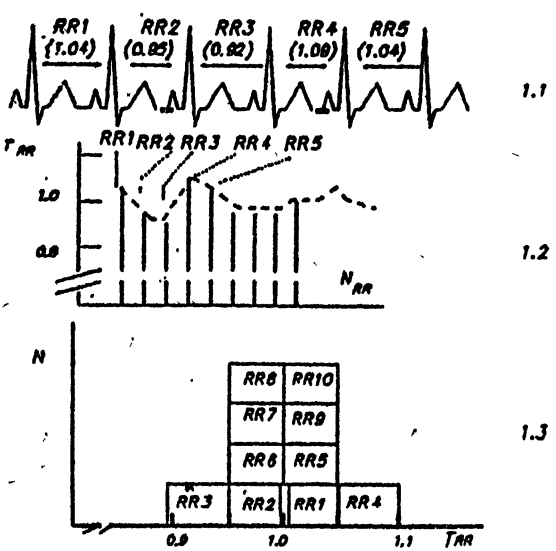

Fig. 1. Methods of RR-intervalogram and a RR-interval histogram construction: 1.1. Initial electrocardiógram (in brackets — RR-interval values in s); 1.2. RR-intervalogram; 1.3. RR-interval histògram. T_RR — RR-interval value (s). N_RR — an ordinal number of RR-interval. N — an ordinal number of RR-interval in a segment of a numerical axis.

Indices 4 – 6 actually show the distribution peculiarities (histograms[1]) of the calculated series σ_{15} in 4 ranges (0 – 5 ms [millisecond], 5 – 10 ms, 10 – 15 ms, >15 msec)[2]. In authors opinion

[1] Histography — way of studying the discrete variable consisting in the investigation of the distribution law of its values as accidental ones in their values series under study. The construction is carried out by the following way: the segment 6f number axis of the variable is divided into small portions; then for each axis portion the quantity of the variable values with the duration corresponding to the this portion is calculated by the discrete values series under investigation; the derived number is plotted on the diagram in the form of a column (bar). A combined diagram is designated as histogram. As an example see one of the variants of the construction of RR-intervals histogram, given on Fig. 1.3 [6].

[2] It is necessary to take notice of the certain artificiality of selected ranges (especially of the range >15 ms). As appears from a publication [5] threshold values of ranges have

indices 4 – 6 allow to investigate the stationarity of SCSR for 300 initial RR-intervals.

The applied complex of SCSR-indices has reliably divided (by discriminant statistical analysis) the patients during the acute period of MI into the patient groups with uncomplicated MI, complicated MI of a medium degree (lethality of 5%), complicated with hemodynamic disorders (lethality of 38%). Dynamical observations have shown a parallelism between the changes in SCSR and the patient condition especially during the acute period. It was found that the rhythm variability, i.e., a decline in the rhythmogram wave amplitudes was in line with the deterioration of the patient state and with the degree of hemodynamic disorders. Besides, the adoption of SCSR index complex allowed for isolating the group of patients whose condition was accompanied by a myocardial electrical instability e.g. severe arrhythmias (extrasystoles of high grades and one third of them with ventricular fibrillation). Rhythmograms of these patients were noted for the portions with a low as well as with a relatively high degree of SR-variations.

The peculiarities of SR-variations found in patients of a different MI groups are clearly seen in the form of averaged histograms for σ_{15}-index distribution (see Fig. 2; on this figure and several following ones an index σ_{15} designated as S15). These histograms show appearence relative frequencies of σ_{15}-index values in 4 ranges (0–5, 5–10, 10–15 и >15 ms).

Naturally, the important data presented in publications [1–5] should not be completed just by establishing the facts: surely they call for a further analysis. This is particularly important for us to answer the questions on the reasons of a high informability of the given index complex and of a mechanism(s) responsible

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been selected in correspondence with experimental data. σ_{15}min-index values equal to 15 ms have been found only in healthy persons therefore threshold values of ranges did not increase above this value (for avoidance of a method sensitivity lowering).

for given peculiarities of SCSR with the patients of different MI groups.

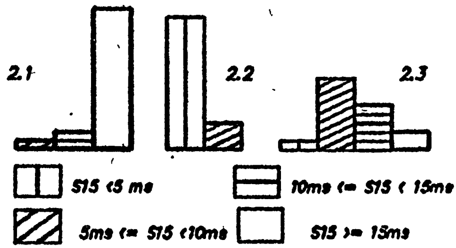

Fig. 2. Histograms of σ_{15}-index (designated as $S - 15$) (millisec., ms) according to a myocardial infarction (MI) course: 2.1. uncomplicated MI, 2.2. complicated by hemodynamic disturbances, 2.3. MI complicated by a myocardial electrical instability. (By a permission of an author [5] and IPP RAN publishing house.)

This fact generated a need for carrying out of a thorough study of the materials given in papers [1–5] and a necessity for a detailed analysis of the peculiarities of SR regulation in MI patients.

2. SOME THOUGHTS ABOUT THE REASONS FOR INFORMABILITY OF THE COMPLEX OF STATISTICAL CHARACTERISTICS OF A SINUS RHYTHM

All the 6 given SCSR-indices allow for obtaining the data on variability (deviation from a mean value) different SR-parameters Thus, it means that actually this complex permits of gaining the information of the wave amplitude parameters occuring at different segments of an initial rhythmogram.

It is well known that a normal SR is, as a rule, accompanied by changes in the periods of RR-intervals. This arrhythmia is connected with respiration acts as well as with other cyclic processes taking place in the organism: tones shifts of an autonomic nervous system (sympathetic and parasympathetic systems), subcortial section of central nervous system, etc. These processes are expressed on the rhythmogram as superimposed relatively high-frequency as well as low-frequency oscillations (by the waves of a different amplitude) [8–10].

As a rule, three types of waves are isolated: respiratory, slow waves of the first and the second order. The respiratory waves have the period from 2 to 8 (–10 s) and are referred to high-frequency ones. The slow waves of the first order — from 10 to 30 s and slow waves of the second order - more than 30 s are considered as low-frequency ones. In these case it is assumed that SR-changes in the time intervals less than 10 s are conditioned mainly by the changes in the activity of a parasympathetic nervous system. The activity of a sympathetic nervous system is expressed as the processes exceeding 10 s level. This is supported by the data obtained during the experiment (see Table 1) which is made on the basis of the materials given in [11].

The investigation of characteristics belonging to all indices included in the SCSR-complex has shown that a high informability of the latter apparently consists in their fixation to the definite segments of the rhythmogram (actually to time intervals) rather than in the use of properly designed formulae for calculation. This provides a means for receiving the information about the intensity of the processes taking place at these very time intervals. We have only two of them: 180 – 300 s (for indices 1 and 2) and 9 – 15 s (for indeces 3 – 4)[3].

With the regard for the data given above it may be explained as follows: Indeces 1 – 2 reflect simultaneously superimposed both high-frequency as well as low-frequency processes caused by the activity of both parasympathetic system as well as of a

[3]If we take into account that MI patients in an acute stage have the heart rate value within the range of 60 – 100 beats per min then the time intervals for 300 RR-intervals are within the range of 180 – 300 s (3 – 5 min) and for 15RR-intervals — from 9 to 15 s.

sympathetic one. Indices 3 – 6 in turn take account of high-frequency processes related to parasympathetic influence only.

Thus, the SCSR-complex actually is a digital filter for studying the low-and-high-frequency processes observed in the sinus rhythm.

Table 1

Comparison of the influence of the autonomic nervous system on the heart, gained during stimulation of sympathetic and parasympathetic heart nerves (according to [11])

Physiological action	Sympathetic nervous system	Parasympathetic nervous system
Common reaction of a heart rate (HR)	increase	decrease
Latent period, s	1 – 3	0,2
Time of achieving the established HR-level during stimulation, s	30 – 60	several beats
Time of achieving the established HR-level when stimulation is stopped, s	30 – 120	several beats

3. PECULIARITIES OF HEART PARASYMPATHETIC CONTROL DURING MYOCARDIAL INFARCTION BY THE DATA ON THE HEART RHYTHM ANALYSIS

The analysis of the materials given in studies [1–5] makes it possible to get an idea of the peculiarities of SR-regulation in the acute phase of MI from the side of both sympathetic as well as parasympathetic nervous systems. It allows for making the SCSR index complex judging by the materials of the previous chapter. The possibility of evaluating the particulars of control action from the side of parasympathetic nervous system is assumed to be the most important factor. It is believed that the data given in Fig. 2 open the clue to understanding of these peculiarities. These data give an idea of the particulars for σ_{15}-index distribution. σ_{15}-index reflect the level of parasympathetic effects in different groups of MI patients. Fig. 3 shows them in a somewhat converted form. All the data given in Fig. 2 are given in Fig. 3 for illustration as a series of successive diagrams with the same scale corresponding to the dimensionality given by the author of papers [5].

In this case they are combined in various compromises on diagrams 3.4–3.7. Diagram 3.6 combines groups with complicated course of disease. Diagram 3.7 combines all the data for the three groups.

It is evident from the data given on diagrams 3.1–3.3 as it has been pointed out in papers [1–5] that the different group indices occupy different positions on the numerical axis.

At the same time attention is drawn to the fact that the assortments given on histograms are asymmetric both for the groups with uncomplicated (diagram 3.1) and complicated hemodynamic disorders in MI (diagram 3.3); this is very essential owing to an adequate representativeness of the group samples.

The peculiarities of these two assortments reside in the where the indices are predominant (so-called modes of histograms); these zones correspond to definite ranges of the numerical axis. The patients with uncomplicated MI have the mode within the range of more than 15 ms (diagram 3.1); as far as the patients with hemodynamic disorders complications are concerned their mode is within the range of less than 5 ms (diagram 3.3).

Only the patients with complications in the form of electric

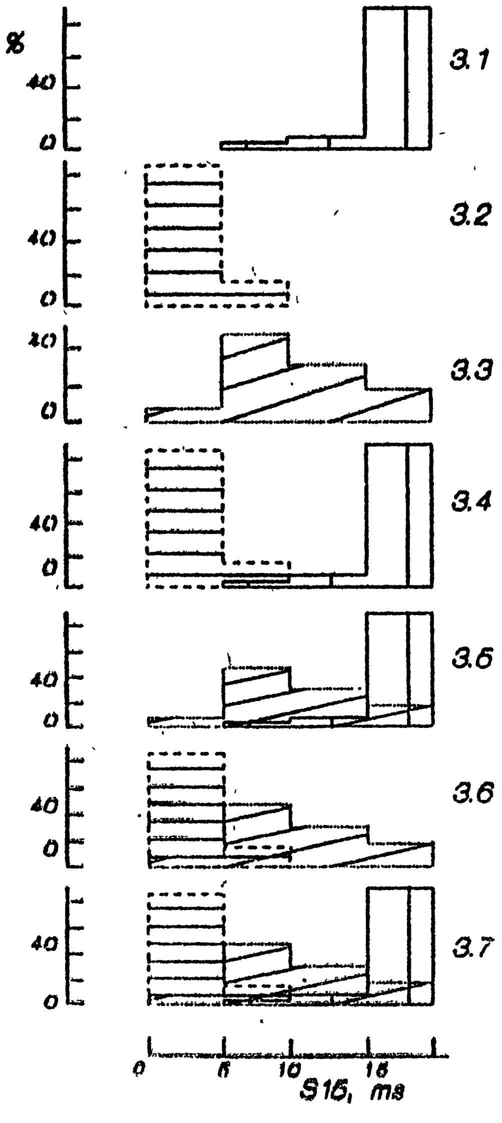

Fig. 3. σ_{15}-index histograms in MI groups: 3.1 — uncomplicated, 3.2 — complicated by hemodynamic disturbances, 3.3 — complicated by the myocardial electrical instability, 3.4–3.7 — combinations of histograms 3.1–3.3 (transformed data of Fig. 2)

instability of myocardium (Fig. 3.2) have the diagram of index distribution in the form close to symmetrical. The consideration of combined data given in Figs. 3.4–3.7 allows for a deep insight into the dynamics of regulatory shifts caused by a certain factor when the MI complications are being developed.

The diagram given in Fig. 3.4 combines the indices found when analysing the groups with uncomplicated MI and with the disease complicated by hemodynamic disorders. The combined diagram has a two peak (two-modal) structure. The latter indicates that we have a distinct demarcation of the groups due to the influence of the above-mentioned factor.

But Fig. 3.5 where the data for the groups with uncomplicated MI and electric instability of myocardium are taken together shows the two-peak contours though the distance between the peaks is less than that of Fig. 3.4.

Yet, the diagram of Fig. 3.6 combining the distributions of both groups with complicated MI has a single-peak outline. This may support the similarity of SR regulation of these two patient groups.

The consideration of the changes in σ_{15}-index as an indicator of the changes process of the complication growth enables one to conceive the chronology of this process (see Fig. 4). The start of this process is given in Fig. 4.1; the different intermediate phases - in Figs. 4.2 and 4.3; the final stage – in Fig. 4.4.

It should be particularly emphasized that the study of the set of the diagrams allows for isolating the two spheres where the data are grouped (mainly, they correspond to the modes of histograms). These spheres are located within the zones of more than 15 ms and less than 10 ms. At the same time the zone between 10 and 15 ms is an intermediate one dividing these spheres. With the data on physiological importance of σ_{15}-index taken into account it is not improbable to assume that the zone of more than 15 ms is noted for the normal functioning of the parasympathetic nervous system. Naturally, a pronounced drop (up to depression) in the parasympathetic activity takes place within the zone less then 10 ms. Taking into account the intermediate zone availability (10 – 15 ms) clearly seen on a number of the diagrams (see Figs. 3 and 4) it may be assumed that it has probably a stepwise change of σ_{15}-index values.

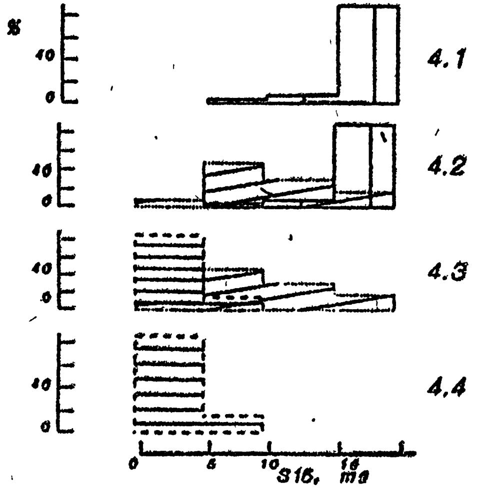

Fig. 4. A possible chronology of σ_{15}-index changes in uncomplicated MI patients (4.1) and during the process of complication appearances by myocardial electrical instability (4.2) and by hemodynamic disturbances (4.3–4.4). See the text for explanation.

The presence of such a step is primarily related to the nonlinear character of the objects under study. Among other things the such step may be conditioned by so-called relaxation oscillations. The data on them from the point of view of the application to the analysis of the available SR- peculiarities are examined below.

4. ON THE POSSIBILITY OF THE SINUS RHYTHM PARASYMPATHETIC CONTROL BY THE RELAXATION OSCILLATION MODE

Relaxation oscillations were previously described for mathematical and physical objects and then for biological processes [12, 13, 14, 15 и мн. др.].

In the seventies A.M.Molchanov pointed the way to possibility for such events in respect to various biological systems (biochemical reactions, populations of microorganisms, etc) [16]. In compliance with the authors option the descriptive signs of this system are: 1) A sudden cessation of functioning when the conditions are slightly changed ("the system dies"); 2) A long absence of "life indications" (the observer may assume the system to be dead); 3) A sudden resumption of functioning.

The vital functions of the system under investigation are approached usually from a few distinct indications (growth, movement, consumption of substratum [probably, in our case from σ_{15}-parameters — V.B.]). Deep processes are rather inaccessible for registration; even continuous registration of the parameters is a hard technical problem. Therefore one may observe only one value z which is a rather complicated function of inner parameters u (quick variable) and v (slow variable) [the author takes the parameters — variables to be the concentrations of substances]:

$$z = F(u.v)$$

In this case the parameter under observation (z) is dependent by some unknown way on parameters u and v. If the system is relating to the relaxation one then the diagram of the value under observation (z) has characteristic ruptures (step) and fractures typical for the quick and slow variables[4] (see Fig. 5).

[4]It is interesting that the relaxation oscillations are also called "ruptured" oscillations (i.e., they differ sharply from the harmonic sinusoidal oscillations) [12, pp. 230–231].

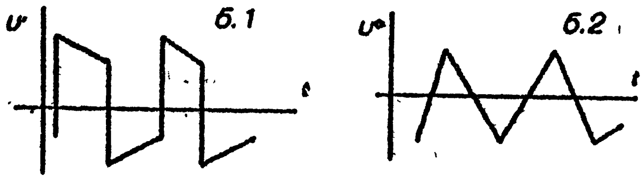

Fig. 5. Graphs of u' and u'' parameters relating to a relaxation system: 5.1. Graph of a quick variable characteristic by jumps; 5.2. Graph of a slow variable fructures peculiar to a quick phase.

This is related to the interrelation between variables u and v (see Fig. 6). Fig. 6 demonstrates that this interrelation is nonlinear and characterized by Z-shaped curve. As this takes place the curve has two zone of stable states (appear as solid lines with arrows) and the segment of instability (separated with a dotted line).

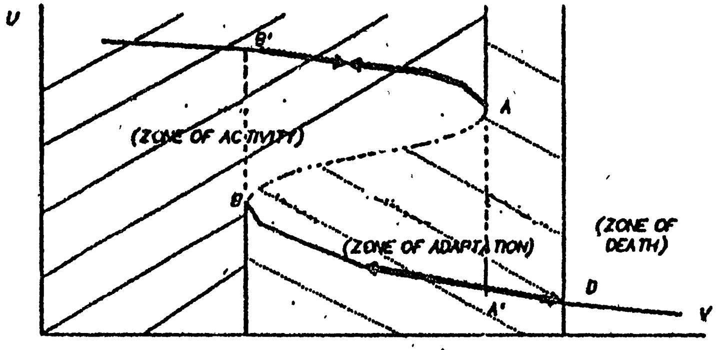

Fig. 6. An interrelationship of a quick variable u and slow variable v in the relaxation system (according to A.M.Molchanov [16]). The upper branch on the graph is the zone of an active stable state of the system; lower branch is the zone of a lower activity stable state (adaptation - shock and death); point D is a boundary of reversible changes. See the text for explanation.

Dynamic changes in the parameters of the system occur by the following way. If the parameters correspond to the zone of the upper stable state, the system will be functioning in this sphere as long as the parameters do not reach point A which represent the boundary of the unstable sphere. This is directly followed by a step-wise drop in the value of quick parameter u with its transition to point A'. At this moment the system will start functioning in the sphere of the lower stable state. In turn this will be in progress so long as parameters do not reach point B - the other boundary of the unstable zone. In this case a rapid rise in parameter u will take place with transition to point B' and, therefore, the system will continue functioning within the zone of stable state till it reaches point A again, etc.

In reality it rather difficult to trace the dynamics of the two parameters at the same time. The common practice is when one may observe only the changes with time in one of the parameters of the mentioned system (or by means of some third index z, for instance, is functionally connected by correlative ratio with this parameter). In this respect the distinctive characteristics of the observed curve of the varying parameter (or index) enable one to refer this system to a relaxation one (see Fig. 7).

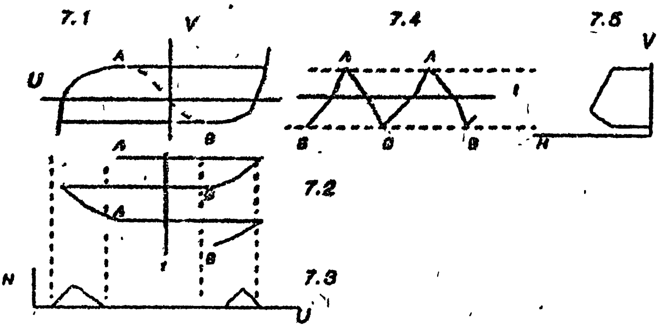

Fig. 7. Possible dynamics graph patterns of quick (u) and slow (v) variables relating to the relaxation system (7.1) obtained during their recording as curves (7.2, 7.4) and as histograms (7.3, 7.4). See the text for explanation.

Diagram 7.1 shows the interrelation between quick parameter u and slow parameter v (in the form of Z-shaped curve). Diagram 7.2 (as well as diagram 5.1) demonstrates an ordinary type of the curve belonging to quick parameter u obtained during permanent registration. The curve is characterized by the periods of slow drifts to the increase (or decrease) replaced by sharp-stepwise changes in the curve amplitude. As this takes place the periods of slow changes in the parameters correspond to the system functioning mode on one of the branches of a stationary state and the sharp shifts — to the transition to the other stationary branch. When the varied parameter is presented discretely in the form of histogram the latter will be of a two-peak character (see diagram 7.3). Diagram 7.4 (as well as diagram 5.2) gives an idea of the registration curve for slow variable v. The curve is characterized by the fractures marked by points $A \dots A$ and $B \dots B$ witnessing to the presence of a quick process stage. When the parameters of this variable are taken discretely the histogram will be approaching by it's form a rectangle without a distinct isolation of the predominance zones.

According to A.M.Molchanov [12] depending on various conditions (for example, parameters of external or internal environment) the system may occupy one or another stationary branch. This corresponds to one of the functional states of the system (see Fig. 6). Due to this factor the author separates the following zones: of activity, rest (shock) and death.

Within the zone of a steady activity the system is influenced by favourite conditions of the external or internal environment. When the environment conditions are deteriorated it passes into the stage of a steady reduced activity (or according to A.M. Molchanov — the rest zone (shock). There are two kinds of outcome in the existence of the system in this state. When the environment conditions are improved the system may pass into the zone of a steady activity with the resumption of a full value functioning of the system. When the deterioration of environment conditions is still in progress and if they come out of the limits of physiological values the irreversible changes leading to the death of the system may occur in it.

The system reaction to the outer influence should be characterized by two different properties — adaptation and steadiness.

Adaptation is the system property consisting in the cessation of the active functioning when the environment conditions are being deteriorated followed by the conversion to the least possible level of functioning. The wider arc $B'D$ (see Fig. 8.1) the more the adaptive reserve is. If the environment conditions are improved the system may return to the active mode. Apparently, besides shock, such states as faint, coma (and probably, just sleep and hibernation), transition of an acute disease to a chronic form, etc, may serve as various examples of a transition to an adaptive mode.

Steadiness is another property of the system to reach a state of a stable activity and to keep it for a long time, although with disposition to vary. The further point C (steady activity) from breakdown point A (see Fig.8.2) the higher the system steadiness is. It is apparent that in these cases the considerable effort is required to force the system out of the activity state.[5]

Definite reserves of steadiness and of adaptation as well are available in each biological system. However, the ratio of their values is different in dissimilar situations. According to A.M. Molchanov, there are two extreme situations: 1) adaptive system without steadiness and 2) steady system without adaptation.

A good adaptive system without steadiness (see Fig. 8.1) is characterized by the fact that it's range of steadiness is minimal (working point C is close to break-down point A) and the adaptation range is increased. In this case the system easily goes to

[5]It is obvious that the influence degree knocking out the system of the stable state will be characteristic for reserve possibilities of the system in this state. Various loading tests are based on this thesis.

shock but due to a increased ability to overcome the unfavorable conditions doesn't die and from time to time comes back to an active state.

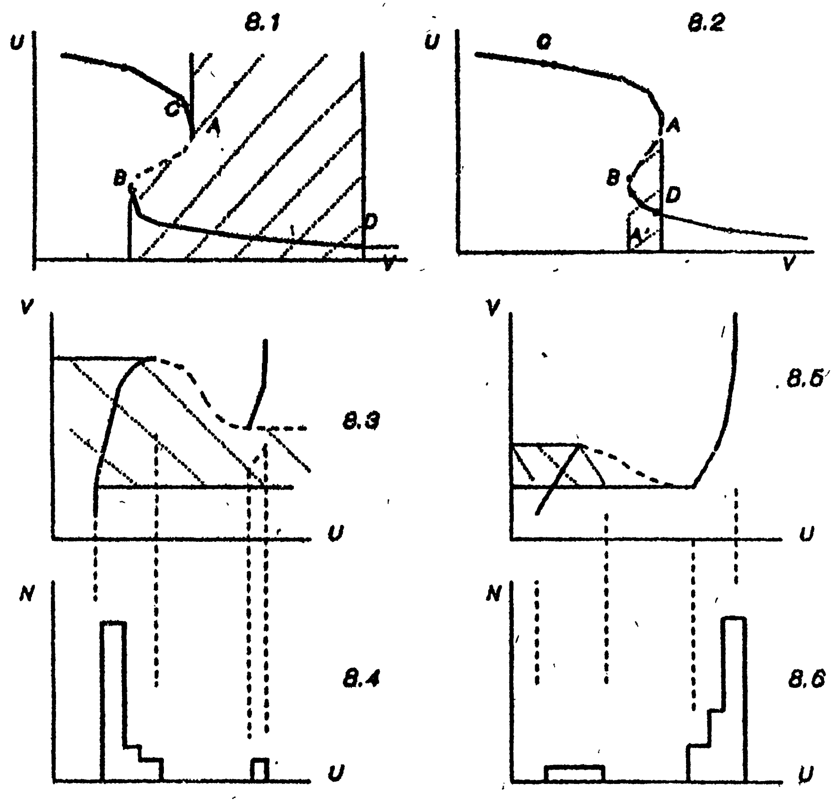

Fig. 8. Patterns of interrelationship of quick (u) and slow (v) variables in cases of an adaptive system without active stability (8.1) and of an active stable system without adaptation (8.2) and their associated possible shapes of u-variable histograms – see Figs. 8.4 and 8.6. Graphs 8.3 and 8.5 are the graphs 8.1 and 8.2 rotated clockwise by 90 degrees. See the text for explanation.

In contrast to it a steady system without adaptation (see Fig. 8.2) retains a high efficiency and may endure severe influences. However, it is free from adaptation reserve (point A' practically coincides with point D). Therefore, any effects causing shock lead to the death of the system.[6]

We suppose that it is possible in some cases to establish the fact that the objects under observation belong to one of the given systems. In this case it is thought judging by the diagrams given in Figs. 5 and 7 that the obtained curves belong to the objects pertaining to systems functioning by the relaxation oscillation mechanism. In it's turn the comparison of the descrete data of one and the same index u (or v or some other index of the parameters correlating with them) allows for isolating the system pertaining to these extreme types. Probably it may be performed during comparison of histograms which should have been observed in the case of a stable system without adaptation and an adaptive system without steadiness (see Figs. 8.4 and 8.6). The latter are obtained for quick variable u.

The comparison of histograms given in Figs. 8.4 and 8.6 shows that they have a clear-cut asymmetry with a marked predominance of the values in the extreme zones of numerical axis. For the cases under consideration they are the extreme left (for adaptive system) and the extreme right (for active system). Naturally, the predominance zones correspond to the prevailing functioning branch for the Z-shaped curve (see Figs. 8.3 and 8.5) shown first in Figs. 8.1 and 8.2.

It should be noted that as a result of a mental superposition of these diagrams one should obtain a symmetric pattern similar to those examined by us when studying σ_{15}-index in Figs. 3.4 and 3.7. With consideration for this one may think with a sound basis that the investigation of σ_{15}-index histogram points to the fact that the parasympathetic system functions by the relaxation oscillations mechanism during MI acute phase.

From our point of view the data obtained on the functioning

[6]Knowledge of life has noted long ago the existence of these two extremes. Suffice it to remind you the proverb: "Oaks may fall when reeds stand the storm".

of the system (organism) under observation in one or another mode is very important from practical point of view. A reliable ascertainment of the presence of one or another state enables the physician from his viewpoint to give an objective assessment of the patients state and to estimate the effects of physical (labour) influence and medical treatment. The information on functioning of the parasympathetic nervous system on one or another branch of the Z-shaped curve probably allows for performing it. We think that the comparison of σ_{15}-parameter characteristics with the data on clinical peculiarities of patients in different MI groups is the basis for this.

When analysing the papers [1–5] on σ_{15}-index given in a converted form in Figs. 3–4 we distinctly see the distributions of this index, corresponding to two extreme positions of the numerical axis: the group of uncomplicated MI and the patients group with disease complicated by hemodynamic disorders.

With consideration for a favourable condition of a patient when passing into a subacute MI period (absence of indication of an acute coronary and cardiac insufficiency and fatal outcomes), the distribution of σ_{15}-index in the group of the patients with uncomplicated MI should comply with the parasympathetic functioning on the branch corresponding to an active state of Z-shape curve.

On the contrary, an acute period of the disease with fatal outcomes in the patient group having hemodynamic disorders with distinct characteristics of σ_{15}-index distribution typical for this group may favour the parasympathetic functioning on the branch corresponding to the state of reduced activity (close to the state of the death of the system).

A group with myocardium electric instability is worthy of notice. The patients of this group were isolated from the group with hemodynamic disorders due to unexpectedly high values of SR-variability and to the development of serious failures in the heart rhythm. We think that the distribution of σ_{15}-index in this group is approaching too close the distribution of the group of patients in a critical state (modes of histograms are located in the neighbouring segments of the numerical axis: <5 ms and 5 – 10 ms). At the same time a considerable part (almost a half) of the distribution portion is within the zone of the numerical axis ($>$10ms) characteristic for the group of uncomplicated MI. Certainly, this witnesses to the presence of transition processes (passing from an active branch to an adaptive one, and backwards). If one can imagine that functioning of the parasympathetic nerve system of these patients not long ago followed the systems with high activity without adaptation then the development of a marked pathology (MI !) leads to the exhaustion of "the stability reserves" nearing point A and passing to the low activity branch of Z-shape curve. In this case the system becomes the so-called autooscillative one (self-sustained oscillation). This fact is indicative of extremely unfavourable conditions for it. The death of the patients may be conditioned by different reasons: in particular by an electric instability of myocardium (various serious arrhythmias).

It should be noted that the revealed regularities of SCSR distribution (in particular, for σ_{15}-index) were found only for an acute MI phase. As this takes place a rather close grouping of σ_{15}-parameters in every isolated groups of patients was found. Apparently, it is considerably governed by the presence of a severe stressor influence such as MI (in acute form). The appearance of unified modes of system functioning is conditioned by this very extreme situation. In this respect, curious and important is remark of the author in study [5] that in a subacute stage of the disease such relations between the distributions in σ_{15}-index were not available. According to the interpretation given by A.M.Molchanov this may be conditioned by the fact that the oscillations close to the critical point even may not occur beyond the stress situation.

5. CONCLUSION

A study of the published data on new heart rate variability investigation made it possible to establish that the complex of proposed indices evaluates a degree of activity for the parasympathetic as well as for the sympathetic nervous system. Moreover contrary to generally accepted methods using 100-500 and more RR-intervals [8, 10] the application of shorter rhythmogram segments (15 RR-intervals) is enough for obtaining the information concerning parasympathetic activity.

The use of the elements of nonlinear oscillation theory methods in the heart rate characteristics analysis allows to formulate a hypothesis of the parasympathetic functioning in myocardial infarction patients by relaxation oscillation mode.

In this case several variants of this mode are possible with the MI patients. The variants correspond to the following biosystems: a) a steady one keeping the activity but with a low adaptation (observed when the disease is manifested favourably); b) an adaptive one but with a low activity reserve (correlates with serious hemodynamic disorders); c) an intermediate one located between the first and the second system with a transition process in progress, probably with self-sustained oscillations, the fact that once again emphasizes the severity of the patients state and clinically is associated with the frequent electric instability of myocardium.

It is necessary to pay attention to the existence of other nonlinear models (except relaxation oscillation one) correponding to clinical data obtained, such as limit cycle near bifurcation (for example, with hard excitation and even soft excitation), strange attractors, etc.[7]

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[7] Accoding to publications [13, 17] all the given models may be of differemt types (the

Thus the studies on heart rate peculiarities could not give a final answer about the real model(s) of parasympathetic control in myocaridal infaction patients. Nevertheless this study is believed to be useful for future planning of the investigations — clinical and experimental explorations.

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so called auto-oscillating systems). The latters are generating undamping oscillations, sustaning both inner conditions as well as the changes of initial conditions of their genesis. Such systems have been firstly isolated by A.A.Andronov in 30-s of 20-th century. He gave them exact mathematical consistence connecting auto-oscillations with Poincare limit cycles. Limit cycle is the closed quiet clearly determinable phase trajectory, where all neibour trajectories of observed system are aspiring to. The term "phase trajectory" belongs to the notion of a phase space. The phase space is a certain multidimensional (one-, two-, ... etc. dimensional) space reflecting the time change of system states. In this case a multitude of numerical values (equal to number of space dimensions) of parameters of the system serve as coordinates of the system state in a certain point of time. The time process may have an image in a form of a certain curve called a phase trajectory. We can often imagine the geometric picture in multidimensional space only mentally. In dynamic systems auto-oscillations may be not only of a periodic character (having a period of exact value) but of a quasiperiodic one (oscillating near any value) and of a stochastic (chaiotic) character as well. Simple examples of such oscillations are oscillations of fiddle strings, oscillations a current in a radiotechnical generator, moving a pendulum in a clock. The mode of auto-oscillation appearance not requiring an initial impact is called a "soft" exitation mode. The systems with oscillations where initial amplitude spontaneously increases belong to the systems of "hard" auto-oscilation exitation. For transition of "hard" excitation system to stationary generation mode an initial exitation (initial impact) of the amplitude more than some critical value is required. Depending upon a certain nonlinearity parameter a common formula has been found for radiotechnic systems. It depicts a appearance of different auto-oscillating systems modes — quasi-harmonic, severely nonsinusoidal and relaxating ones. [13, pp.225–226] Particularly complicated nonperiodical (stochastic) limit cycles may be attributed to strange attractors. In particular, they are characterized by existense of a phase space "attracting" region with trajectories of system under study being not stable and of a complicated and intricate behaviour.

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