Original research

ECG periodic table: a new ECG classification based on heart cycle phase analysis

Mikhail Y. Rudenko[1*], Olga K. Voronova[1], Vladimir A. Zernov[1]

[1] Russian New University, 22 Radio St., Moscow, Russia
[*] Corresponding author: Phone: +7 (8634) 31-24-03. E-mail: cardiocode.rudenko@gmail.com
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Aims The article considers the development of the periodic table of ECG phase changes which should reflect the variety of the ECG curves and can be used as reference system for diagnostics purposes.

Materials and methods More than 5,000 ECG records were studied. They were recorded as original single-lead ECG of the ascending aorta. This fundamentally new ECG lead system reflects all processes in cardiovascular system. It was named by its developers the "ECG – HDA". Basing on the theory of cardiac cycle phase analysis, the authors defined deviations from the normal ECG curve. Clinical tests were conducted and descriptions based on the laws of cardiometry were provided.

Results A fundamentally new system of the ECG curve evaluation has been developed.

Conclusion It is stated that all the variety of the actual ECG curves can be divided into 10 groups. Each group contains 4 levels of characteristic changes, starting from the norm up to and including critical deviations from the norm. The results are presented in the "ECG phase changes periodic table". The table can be used for very precise diagnostics. The periodic table enables assessing the capabilities of the practical application of electrocardiography from a new point of view.

Keywords Cardiometry • Cardiovascular system diagnostics • Cardiac cycle phase analysis • ECG–HDA

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Introduction

Cardiovascular system diagnostics based on the ECG curve analysis has never taken into account the processes of the cardiac cycle phase structure. According to the existing standards [1,2,3], the ECG was treated as a set of segments, intervals and waves. Herewith, the functional interrelation of the above elements was not proved. Examination and establishing diagnosis were based on the practical description of the ECG in every individual case. It was assumed that the more ECG channels recorded in every medical case, the more probable is the reflection of the process under diagnosis in the ECG curves. Herewith, the methodological error and systematic error were not taken into account. This approach became conventional. It consists in collecting the descriptions of the medical cases. The collected data enabled creating a global ECG data base [4]. However, none of the cases from the above mentioned data base as well as the cases mentioned in the standards, was described from the point of view of the laws of natural science which provide the logics of evidence basing on the cause-and-effect relations of the observed phenomenon and the factors causing its occurrence. There existed no fundamental theoretical models of hemodynamics which could provide the proper mathematical description of the blood flow through the vessels. Consequently, no concepts of the reference ECG curves and their functional relationships were offered. It means that fundamental classical measurement principles were not included in the existing standards. The practical use of the standards was limited to statement of facts, and the possibility of modeling the diagnosis was not used. The existing standards show a number of inconsistencies. Practicing physicians need much time to compare the real multi-channel ECG recording in order to trace its agreement with the existing standards. However, in most cases precise diagnosis can not be guaranteed.

Materials and methods

For development of a fundamentally new system of the ECG analysis the method of cardiac cycle phase analysis and hemodynamic equations by G. Poyedintsev and O. Voronova were used5. The ECG of the ascending aorta should be recorded. Unlike the already known ECG leads, it contains information about all phase processes in every cardiac cycle5. The location points of the ECG electrodes are shown in Fig.1. The new single-channel lead system enables the ECG signal recording reflecting all processes occurring in the cardiovascular system. The shape of the single-lead ECG can be seen in Fig.2 herein. As opposed to the standard multi-channel ECG leads, it can be provided with metrology that guarantees a minimum methodological error [5, 6, 7].

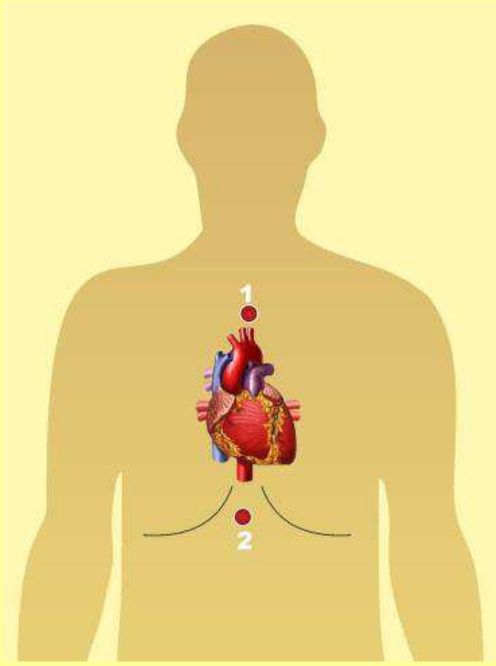

Figure 1. *Location points of the electrodes for recording the ECG of the ascending aorta.*

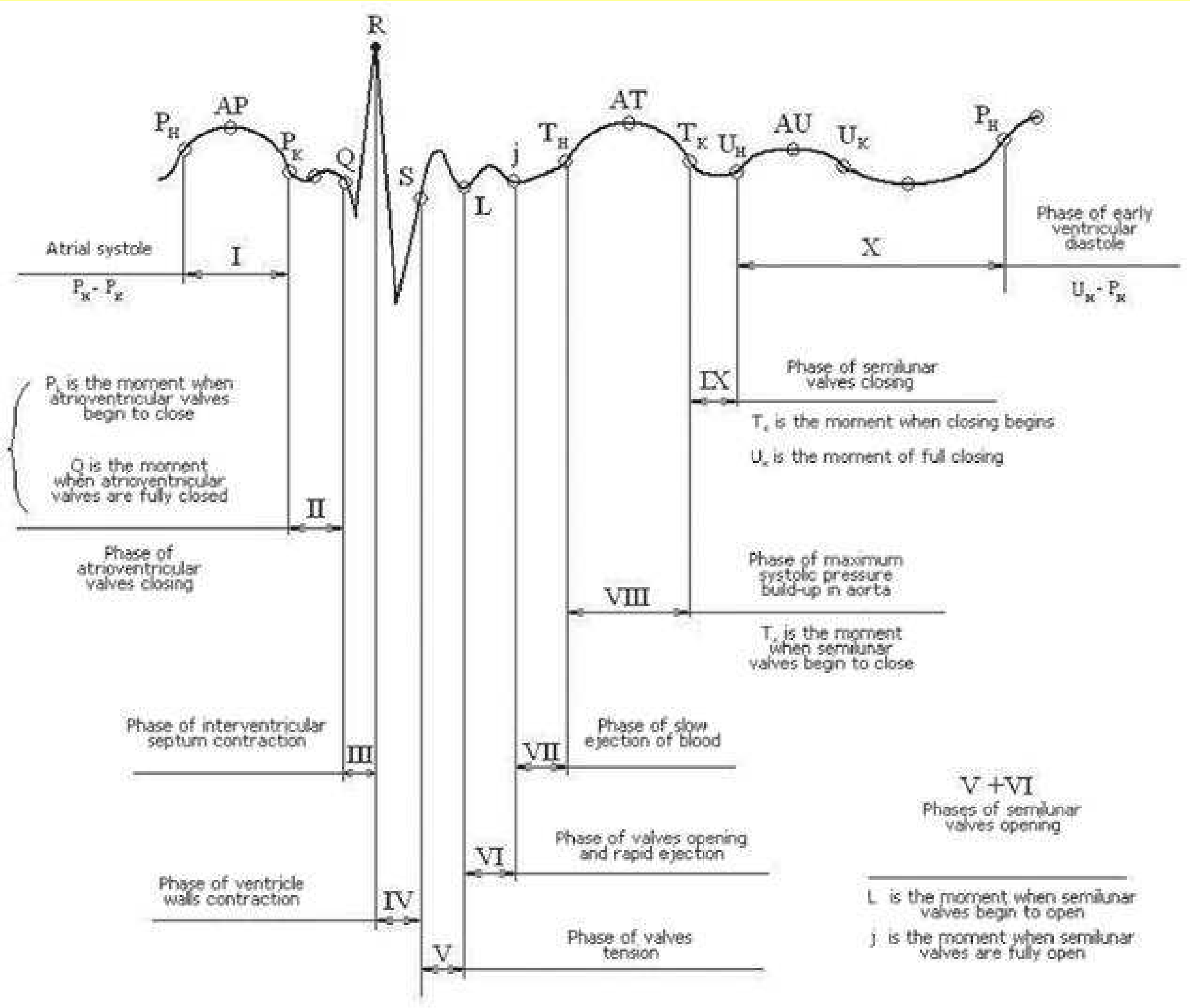

Figure 2. *Phase structure of the cardiac cycle according to the ECG curve.*

Amplitude of every of the 10 cardiac cycle phases reflects the relationship between the amplitude of the muscle contraction and the respective anatomic part of cardiovascular system [5]. The process of the amplitude change can be shown by identifying conditional zones of the norm, its limits and pathologies [6]. The mentioned zones are shown in Fig.3.

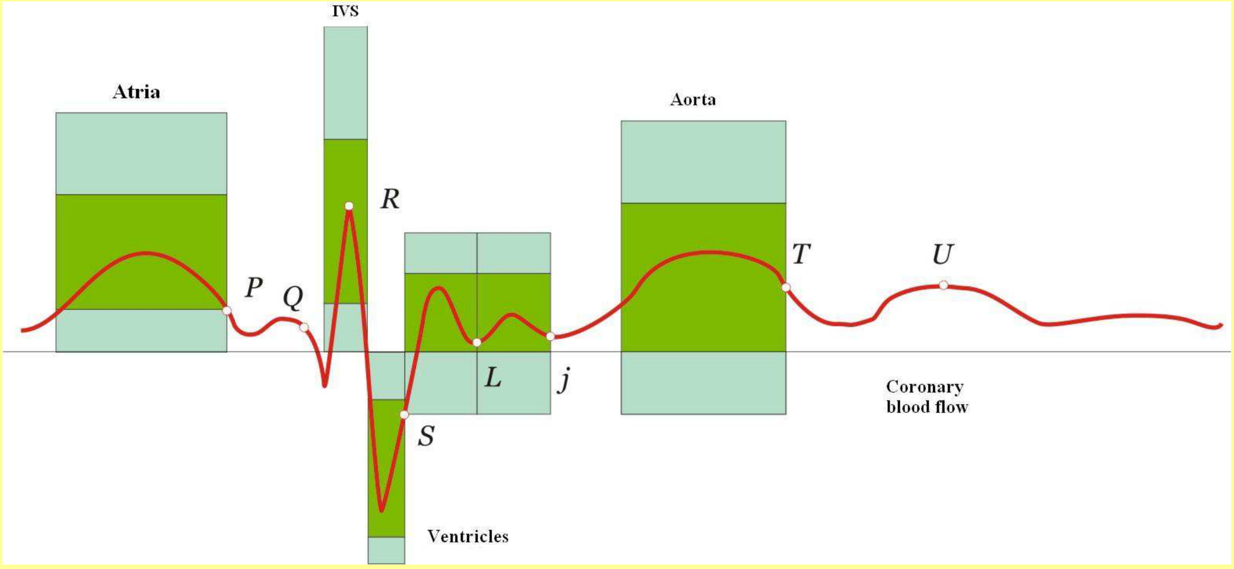

Figure 3. *Color-marked ECG – HDA wave amplitudes relative to isoelectric baseline: the green-bar field indicates the norm, the yellow one indicates the norm boundary, the white field is used to indicate pathological cases.*

Table 1. *Coefficients of the ECG wave amplitude increase*

ECG waves	P	R	S	L	T
The amplitude which compensates the decreased contractile function of the heart adjacent segment	+2,0	+2,0		+ 2,0	+2,0
The amplitude is within the norm	+ 1,5	+1,5	- 0,5	+1,5	+1,5
The norm	+ 1	+ 1	- 1	+ 1	+ 1
The amplitude is within the norm	+ 0,5	+ 0,5	- 1,5	- 0,5	- 0,5
The muscle contraction amplitude is below the norm (except for wave S)	+ 0,25	- 1,5	- 2,0	- 1,5	- 1,0

The processes responsible for changing the ECG curve may be divided into ten function groups, namely:

1. Natural changes caused by physical activity.
2. Cardiac insufficiency:
    2.1. Septal contraction.
    2.1. Myocardial contraction.
    2.3. Septal and myocardial contraction.
3. Synchronization of systemic and pulmonary circulation hemodynamics:
    3.1. Arrhythmias.
    3.2. Sudden cardiac death signs and symptoms.

4. Heart valve function:

    Aortic valve opening.

5. Anatomic continuity of septum:

    Ventricular septum defect (VSD).

6. Coronary flow performance:

    6.1. Thrombus formation.

    6.2. Sclerosis development.

Results

The "ECG phase changes periodic table" is a result of a long-term research work (see Fig.4).

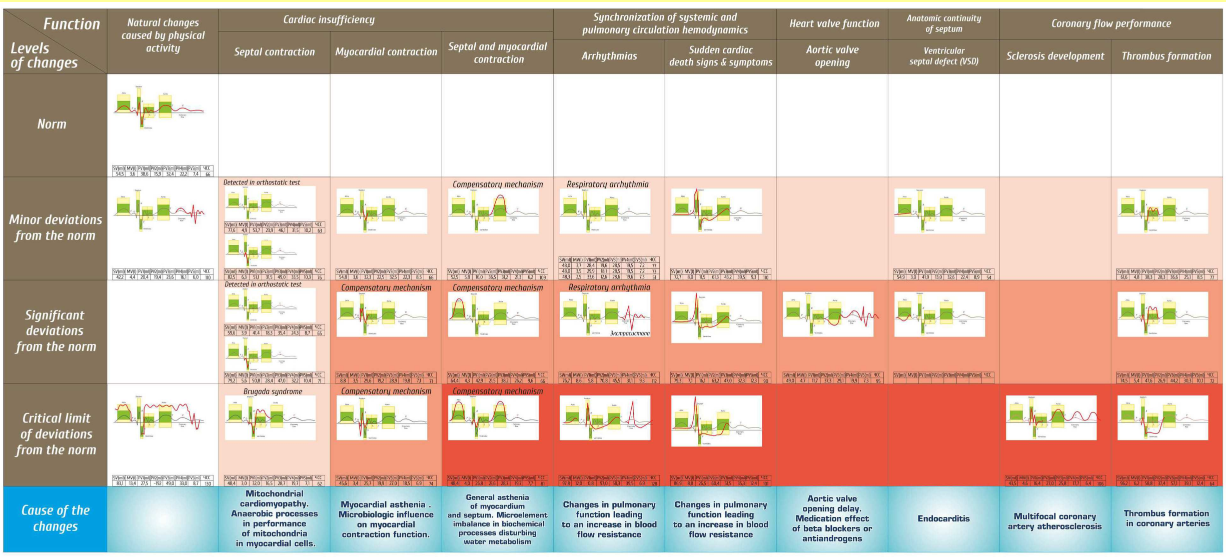

Figure 4. *ECG phase changes periodic table.*

The ECG phase changes periodic table covers the ECG – HDA curves that are used to detect the pathologies of the cardiovascular system function. With the help of the ECG it is possible to trace 10 functions mentioned above. Each of the functions can be traced within the norm as well as within the critical limits of deviations from the norm. The ECG phase changes periodic table includes 30 characteristic ECG – HDA curves. The other curves that can be practically observed are regarded as transitional ones, and can be classified depending on the phase changes characteristic of definite functions.

Let us consider the changing of the ECG – HDA phase amplitudes and the values of the blood volumes that are characteristic of evaluation of the septal contraction function (see Fig.5).

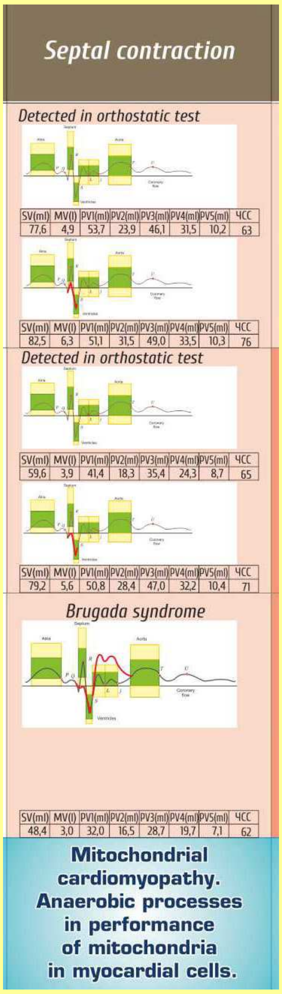

***Figure 5.** ECG – HDA phase changes characteristic of mitochondrial cardiomyopathy in the septum.*

Mitochondrial cardiomyopathy is the most frequent pathology of the septum. This pathology is caused by abnormality in operation of the mitochondria in the septum that can lead to water metabolism disturbance and cell swelling. The pathology can be detected only in orthostatic test. Comparing ECG – HDA in both tests it is possible to trace the difference in R-wave amplitudes which is characteristic of the septal contraction.

During the orthostatic test not only the R-wave amplitude is changed, the phase blood volumes are changed as well. Thus, in supine position the minute volume MV=4,9 l/min whereas in standing position MV=6,3 l/min. These characteristics are considered as minor deviations from the norm. The people having these changes do not experience any specific problems in their everyday life. However, in case of development of this type of pathology, the symptoms of cardiac insufficiency can be observed. Herewith, the heart pumps smaller volumes of blood. In standing position MV=3,9 l/min whereas in supine position MV=5,6 l/min. The amplitude of the septal contraction becomes smaller and is on the level of the isoelectric baseline (Fig.5) which is characteristic of significant deviations from the norm.

In case of further pathology development the ECG – HDA curve is characteristic of the known in classical electrocardiography Brugada syndrome. There is no R-wave, and phases S – L and L – j have high amplitude. It is defined by the compensatory mechanism. It maintains the tension of the phases due to the weakness of the heart muscle. The weakness of the heart muscle contributes to the low value of the minute volume MV=3,0 l/min, that is characteristic of the critical limit of deviations from the norm.

The norm is MV=3,6 l/min. It is shown in the upper left corner of the Table.

The other system segments shown in the Table were systematized according to the same principles.

Discussion and conclusions

Creation of the presented system is a logical development of the research of the cardiac cycle phase characteristics [5]. Considering a huge volume of the conducted significant research work and a great variety of recorded signals, the objective laws of formation of the cardiac signals phase characteristics have been traced. Thus, it becomes possible to trace and systematize the most characteristic ECG – HDA curves typical for different stages in pathology development for different functions of the cardiovascular system.

The study of the existing classical standards raised many questions. The attempt of using them for the system creation did not prove to be a success. The existing inconsistencies within the standards appear significant.

But it should be noted that the present research work follows the certain issues that have been treated in the papers by Marek Malik, Jose Jalife, Peter W. Macfarlane and Nikus K.

The newly developed system can not be regarded as an absolutely complete table. The cases of the function of the aortic valve, the influence of the coronary artery atherosclerosis and the cases of a discontinuity of the septum require further study. However, the system proved to be effective in its practical application. Thus, the practicing physician using the single lead ECG – HDA will be capable of making diagnosis and monitoring the further treatment process.

Statement on ethical issues

Research involving people and/or animals is in full compliance with current national and international ethical standards.

Conflict of interest

None declared.

Author contributions

M.Y.R., O.K.V. and V.A.Z. developed the concept, analyzed the data and prepared the manuscript and, M.Y.R. drafted the manuscript and read the ICMJE criteria for authorship. All authors read and approved the final manuscript.

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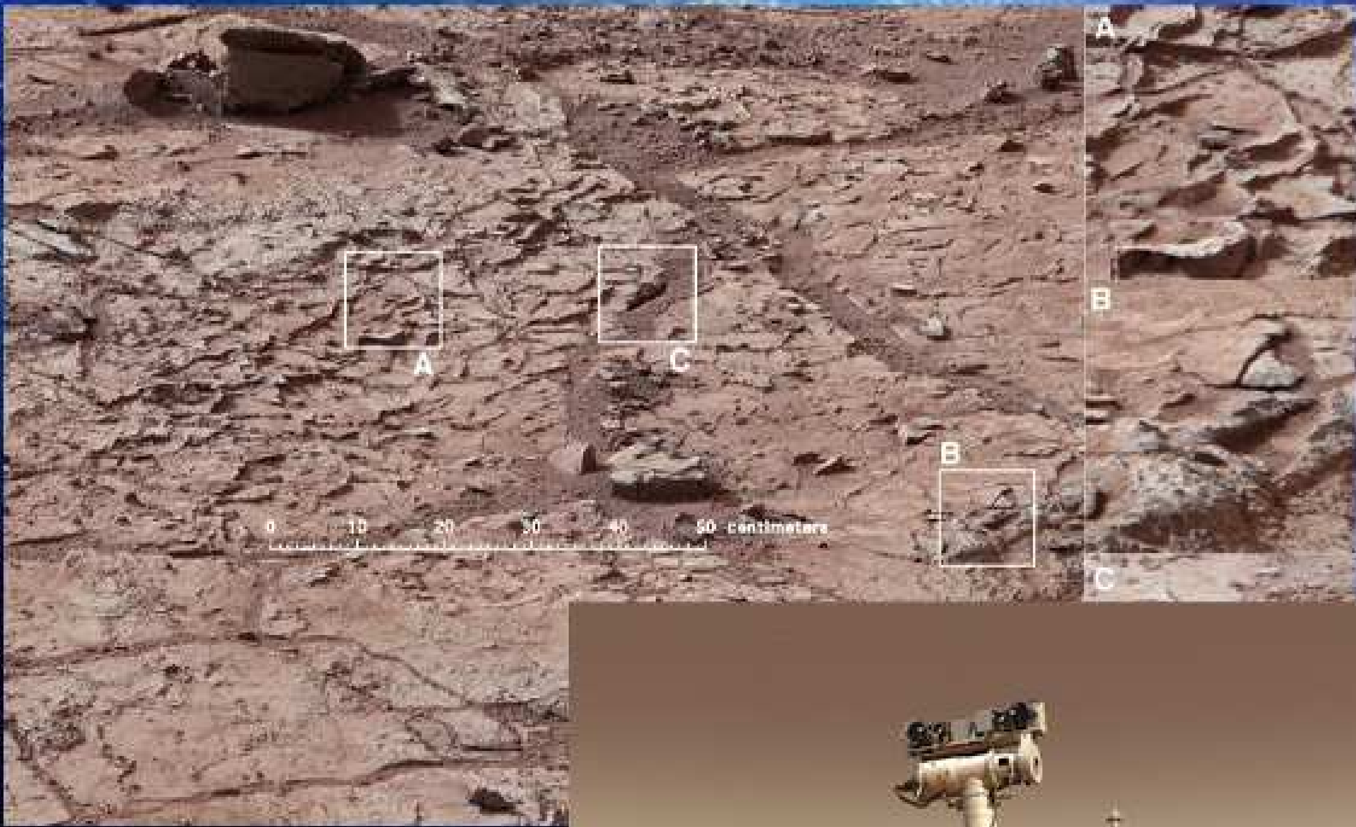

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