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**BIOTECHNICAL SYSTEM OF AUTOMATIC CLASSIFICATION SCATTERGRAMS AND  
EVALUATION OF ATRIAL FIBRILLATION OUTCOMES**

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**Abstract**

In this paper is considered structure biotechnical system intended for differential diagnosis of scattergrams or autoregression clouds (ARC) in patients having an atrial fibrillation. Special algorithm classifies ARC and calculates an indicator of preservation of the function concentration of the sinus node for each type of ARC and after that forms the final conclusion about the forecast of recovery sinus rhythm. Assess of effectiveness included 290 persons with coronary heart diseases in age of 47 to 70 years old having the single episode of atrial fibrillation. Calculated criteria of efficacy such as: sensitivity, specificity and predictive accuracy were high: 97.1%; 87.1%; 94.4%.

**Keywords:** biotechnical system, sensor of pulse, micro structure models, autoregression clouds, algorithms, atrial fibrillation, prediction of outcomes.

**Introduction**

Any task of prediction should be conducted to the internal complexity of the problem and its social importance. As is well known syndrome of atrial fibrillation (AF) represents a serious financial problem for public health. Atrial fibrillation encountered in 0.4% persons in the adult population. According to the results of the Framingham study found that AF frequency increases to 10% in people over the age of 65 years compared with a frequency of 2-4% in people over the age of 60 years.

Atrial fibrillation may be accompanied by the life-threatening complications. Based on US Census data, the forecast growth in the number of patients suffering from so-called "non-valvular" forms of AF, is as follows: in 2004, 2.3 million people were registered with a similar diagnosis in 2020 is projected to rise to 3.3 million people and to the 2050's. - 5.6 million people [1], [2].

The forecast of the possibility recovery and preservation of sinus rhythm in atrial fibrillation is important when choosing a strategy of treatment [3], [4].

In our opinion the revealing of the measure influence of sinus node on forming heart rate variability in patients with atrial fibrillation will allow predicting results of defibrillation implemented via electro impulse impact and also recovery of sinus rhythm with antiarrhythmic drugs. The goals of treatment for atrial fibrillation include regaining a normal heart rhythm (sinus rhythm), controlling the heart rate. The choice of methods treatment is carried out in accordance with principles STAF [5], [6], [7]. Therefore, in patients with a history of atrial fibrillation, Cleveland Clinic surgeons treat the atrial fibrillation during other types of cardiac surgery.

Solving the problem of the usefulness recovery of sinus rhythm it is usually based on general clinical research methods that do not always produce the correct results. Physicians' algorithm for an evaluation and prediction outcomes of atrial fibrillation, as a rule, relate to heuristic procedures. Doctors in making one or other prognostic concepts often refer to the experience and intuitive diagnostic [6].

For the purposes of classification of the violations sinus rhythm by different authors are described the methods probability analysis, correlation rhythmography, scatterography [8], [9]. Apropos, these studies were more experimental and methodological orientation, rather than clinical.

In our view this method might use for differentiation various forms of scattergrams in automatic mode. In a pinch, for example, the pre-treated information in the form of autoregressive cloud could be submitted for the consideration to medical expert, who performs a conclusion about the authentic autoregressive cloud. However, as has shown analysis of the scientific literature that first system or second system does not exist in medical practice.

The system of automatic forecasting outcomes atrial fibrillation by using of multi-leads electrocardiogram in the scientific literature had been observed. It should be emphasized that for achievement formulated goals in developed algorithm had been used a complicated mathematical method known as weighted principal component analysis. It should be also noted that this system uses when is performing the procedure of catheter ablation [10].

These facts motivate the interest in predictive features that can be extracted without risk of the patient in a cost-efficient manner, as those derived from analysis of the scattergrams.

Consequently, the topically is the search for mathematical methods of forecasting and restore sinus rhythm. Currently, hardware and software represents new opportunities of the processing medical data [11].

### **Research problems:**

1. Develop the module for automatic input and processing of electrophysiological information in mode on-line.
2. Create an algorithm for the differential diagnosis types' autoregressive clouds.

3. Estimate of the clinical effectiveness functioning of biotechnical system to forecasting of the atrial fibrillation outcomes.

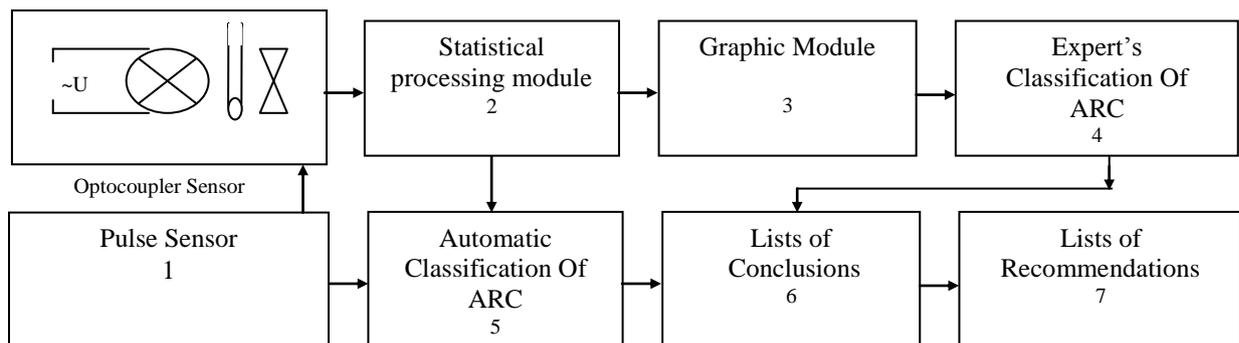
### Material and methods of research

They include the use of method modeling and system analysis with decomposition of the purposes and functions developed of biotechnical system. An analyzing the clinical data was based on the methods of mathematical statistics, methods of recording electrophysiological data: the rhythm of testing or an analysis of heart rate variability (HRV).

In this system is stipulated a practical use of technical devices and software tools to optimize of make a decision about prediction of outcomes at atrial fibrillation. Before, proceed to consider the structure of an automated system of data processing, it is need to consider input and processing electrophysiological data.

For the purposes of entering the electrophysiological data in the on-line regime the special automatic module had been used [12], [13], [14]. This module has the special sensor of pulse consists of three main parts namely: an analog amplification circuit and an allocation of signal, and 8-bit microcontroller with integrated analog-to-digital converter and also unit of the matching of signals level of reception and transmission to connect the device to the serial port of a personal computer.

Thus, the technical part of the system includes a personal computer and interface with analog-to-digital converter (ADC) and corresponding sensor having reliable electrical isolation. This decoupling electrical chain is realized by way of utilizing of the photodiode and phototransistor. Block diagram of biotechnical system is shown in “Fig. 1”.



**Figure 1. The automatic recognition system for autoregressive clouds**

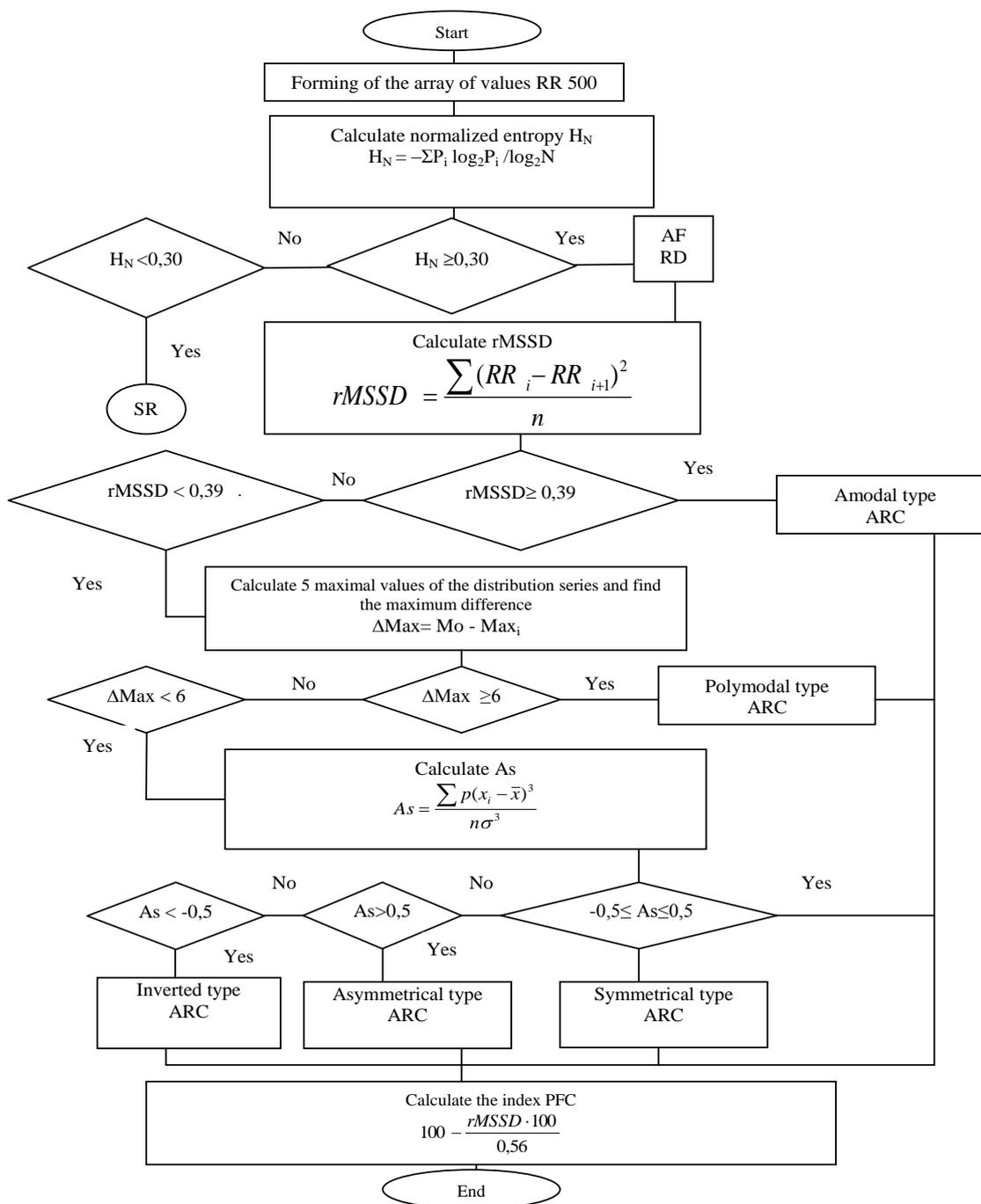
The system has a special knowledge base which allows to calculating, analyzing and graphically constructing autoregressive clouds. For automatic recognition of pattern scattergrams we have developed a special algorithm. The logic classification algorithm of autoregressive clouds is considered in the “fig. 2”. Thus, a general algorithm for the differential diagnosis of ARC can not be created on base of single indicator. We consider the set of parameters that allows to carrying out step by step the classification AR clouds.

Consider the sequence of decisions in accordance with the formulas presented in “fig. 2”.

In the first step of the algorithm from a class of disorder automatic function is allocated the class atrial fibrillation with reliable diagnosis (AF RD).

In the second step are classified low modal classes and in the third step are recognized polymodal classes.

In the fourth step of the algorithm is implemented differentiation of all monomodal classes on the symmetrical, asymmetrical and inverted types. In the fifth step of the algorithm is calculated the preservation of the function concentration (PFC SN) of the sinus node for each type and is formed the final conclusion about the forecast recovery sinus rhythm.



**Figure 2. Algorithm of differential diagnostic ARC**

If: PFC SN = 0% -54%, then the perspective of a favorable prognosis is doubtful.

When PFC SN=55%-69% then is predicted satisfactory probability of a restoration of sinus rhythm.

If PFC SN > 70% then is predicted a high probability of recovery of sinus rhythm.

rMSSD index, which reflects the functional opportunity of the sinus node to the concentration of the heart rhythm, shows that the greatest loss of this function is marked at amodal and multimodal type ARC, and the lowest in the symmetric type ARC. Inverted and asymmetric types of ARC occupy an intermediate position. Expressed ventricular arrhythmia, accompanying an atrial fibrillation leads to a wide scatterings' of points in the plane. First of all we would like that developed algorithm by making decisions about outcomes atrial fibrillation performed it with level of errors near  $\pm 10\%$ . Start of clinical trials was realized by way of trained sample of 60 persons having at the moment of examination the single episode of atrial fibrillation. These were patients with verified diagnosis of atrial fibrillation. The verification of diagnoses was carried out in clinical conditions. Syndrome atrial fibrillation was revealed in patients with coronary heart disease in age of 47 to 70 years old. It was showed that algorithm correctly performed the classification of autoregression clouds in 93% cases and incorrectly recognized it's in 7% cases. Of all 93% correctly recognized cases these were 76% of true positive responses and also in 17% cases there were true negative responses. Errors of diagnostic included 7% cases and of which 4% was hyperdiagnostic and only 3% fall on hypodiagnostic. Therefore an ability of the algorithm to capture the pathology or sensitivity turned out to 96%  $[76/(76+3)]100$ , and the ability of the algorithm to realization a function of the differential diagnosis or specificity was 81.0%  $[17/(17+4)]100$ . The predictive accuracy amounted 95.0%  $[76/(76+4)]100$ .

Verification of the algorithm of differential diagnosis of AR clouds, carried out also on an examinational group of 230 persons having the single episode of atrial fibrillation. Syndrome atrial fibrillation was revealed in patients with coronary heart disease in age of 45 to 65 years old.

The results of verification algorithm on examinational sample are presented in Table 1.

**Table 1: Evaluation of complex classification algorithm of auto-regression clouds on examinational sample.**

№	Type of ARC	Total Number	Correctly Recognized		Incorrectly Recognized	
			True Positive Response	True Negative Response	Hypodiagnos.	Hyperdiagnos.

1	2	3	4	5	6	7
1	Symmetrical	4%	2.6%	1%	0.3%	0.1%
2	Asymmetrical	50%	33.4%	15%	0.2%	1.4%
3	Inverted	6%	6%	0%	0%	0%
4	Polymodal	30%	15.5%	11%	1%	2.5%
5	Amodal	10%	9.5%	0%	0.5%	0%
6	Sum:Persons %	230-100%	154-67%	62-27%	5-2%	9-4%

From the presented data in Table 1 it follows that this algorithm demonstrates high efficiency because it allows to correctly recognizing ARC in 94% cases (67%+27%). Recognition errors accounted for 6% and of which 4% was hyperdiagnostic and only 2% fall on hypodiagnostic.

The ability of the algorithm to capture the pathology or sensitivity turned out to 97.1%  $[67/(67+2)]100$ , and the ability of the algorithm to realization a function of the differential diagnosis or specificity was 87.1%  $[27/(27+4)]100$ . The predictive accuracy amounted 94.4%  $[67/(67+4)]100$ . The greatest number recognition error falls on the asymmetric and multimodal type scattergram.

## Resume

Modern technologies helps facilitate making a decision of different outcomes atrial fibrillation by providing detailed visual (graphic) and quantitative information about degree of preservation of the function concentration of the sinus node. More precisely, we aim at characterizing the rMSSD of heart rate variability index in an algorithm so as to predict AF outcome by applying the calculation of PFC SN indicator.

One challenge for the performed studies was the development of the adequate models and algorithms and also retrieval of set of indicators for discrimination scattergrams, and whether their reliability can be improved in patients with a form that exhibits unusual characteristic.

Another challenge was to define the relationship between indices derived from the training set and indices derived from the examinational sample.

Overall it is particularly important to note that the revealed facts of the recognition different scattergrams in patients with atrial fibrillation may be used for primary prediction of possibility restoration of sinus rhythm.

Vexed question about possible accordance of the forecast restoring sinus rhythm and its subsequent preservation arises over and over again before us. The proofs retrieval of the forecasting models adequacy to actual clinical manifestations of atrial fibrillation syndrome continued in the remote period.

It was established that sinus rhythm was restored during the first day from onset treatment, in all patients by using drugs. Further observations showed that sinus rhythm in 80% of patients is preserved more than 12 months. All of these patients had a good prognosis. Finally, 20% of patients having satisfactory prediction had a returned to atrial fibrillation in the period from 3 to 6 months of observation. Of these, in 10% of cases were marked amodal types of scattergrams. And also in 10% of cases were noted multimodal types of autoregressive clouds.

Consequently satisfactory prediction of the probability of recovery to sinus rhythm does not mean the possibility of a satisfactory preservation it for a long period of more than 6 months.

## **Conclusion**

1. The module for automatic input and processing of electrophysiological information functioning in mode on-line is developed. The module operates in a Windows environment, and includes a pulse sensor and receiver of pulse that have a reliable electrical isolation. Module of processing signals from sensor of pulse is started on a separate stream with a high priority.

2. The developed algorithm includes the set of parameters that allows carrying out step by step the classification autoregression clouds. First of all is allocated the class atrial fibrillation with reliable diagnosis.

Last step of the algorithm allows to calculate an indicator of preservation of the function concentration of the sinus node for each type and to form the final conclusion about the forecast recovery sinus rhythm.

3. Qualitatively new biotechnical system of the intellectual analysis of data having an applied nature in cardiology was created in carrying out of the present study.

By means of this biotechnical system was realized the outcomes prediction function of atrial fibrillation in patients with coronary heart disease.

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