# Multidiagnostics study of postoperative cognitive disorders

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## Introduction

The analysis of works of domestic and foreign scientists shows that the results of anesthesia frequently, especially for elderly patients, negatively affect the state of cognitive functions in the postoperative period [1]. Therefore, the modern diagnosis of post-operative cognitive dysfunction (POCD) in the early stages, when changes are potentially reversible, and to develop methods for preventive and corrective cerebroprotective therapy on the background of adequate correction of homeostasis acquire important practical significance.

Objective methods for the assessment of violations of cognitive functions available to the anesthesiologist in everyday practice, does not currently exist. Such methods include electrophysiological assessment of psychomotor functions (the ability to create, save and execute motor program) with the help of stabilography.

As integral characteristics for quantifying the anesthetic component of the operating aggression, the authors propose to use the results of stabilographic studies of the patient in combination with the assessment of his cardiac rhythm, especially with the detection of ventricular extrasystoles (VE). The urgency of the problem of diagnosis is not in doubt due to their high prevalence (more than 62 % of all extrasystoles) and the most important role in the development of sudden cardiac death (SCD), therefore, it is necessary to improve algorithms for the detection of ventricular arrhythmias based on analysis of electrocardiosignals (ECS).

The aim of this work is the search for adequate anesthesia, based on the study of the manifestations of postoperative cognitive dysfunction using the system of «WebMultiMedic» providing a comprehensive assessment of the dynamics stabilographic and electrocardiographic indicators.

## Materials and Methods

In result of cooperation authors with LLC «BIOSOFT-M» (Moscow, www.biosoft-m.ru) is developed a unique system of remote multidiagnostic of patients with dysfunctions of the locomotor system during the postoperative period. Technique, implemented in the system allows passing on the empirical, approximate recommendations to the exact values calculated on the basis of multifactorial characteristics of each patient and synchronous recording of the results of complex research of patient by means of computer stabilography, electrocardiography, electromyography, electroencephalography with remote multidiagnostic system «WebMultiMedic» [2, 3]. Rising of the quality of diagnosis is achieved through an integrated synchronous registration, processing and analysis of diagnostic signals of multiple research techniques of body functions as well as through the implementation of remote examination of patients on the basis of mobile data communications via Internet. Force plate, electrocardiograph, electromyograph and electroencephalograph combined on the basis of specialized hardware and software into a single system that performs remote examination of patients outside hospitals or in other places. Authorization of doctor and patient on Web-server is performed automatically by means of the keys that contain identifier codes and licenses for the types of data operations and modes of examination of a patient. Web-server of functional diagnostics implements the infrastructure to support remote communications in online and offline examinations, a set of operations performed by a physician in during the analysis and processing the results of diagnostics, storage of patient data and real-time video communication for remote consultations.

**Figure 1**

The main software includes the Romberg test, psychological tests, and special research tests designed by original techniques. [4].

The system provides a detailed analysis of the stabilometric parameters and the frequency measurement of heart rate and the amplitude-time parameters of the ECS; performs analysis of heart rate variability, however does not allow to detect ventricular extrasystoles.

Developed an original method of detecting ectopic cardio pulses [5], based on the analysis of the physical nature of the formation of ventricular extrasystoles. Upon detection of ectopic cardio pulses joint processing of the two ECG leads S is performed so that the same QRS-T complexes are mutually compensated. If you experience ectopic complexes the ratio of signals 1 and 2 lead changes, and thus on the signal S appears a surge, which is detected by the threshold device.

One of the variants of implementation of the method is the partitioning of the ECS in each of the leads on the positive and negative components S, and the choice of four weighting factors k1+, k1-, k2+, k2-, so that in the time intervals corresponding to the appearance of the typical complexes, the value of the signal S tends to zero:

$$S = k_1^+ \sum_{i=1}^{N} X_{1i}^+ + k_1^- \sum_{i=1}^{N} X_{1i}^- + k_2^+ \sum_{i=1}^{N} X_{2i}^+ + k_2^- \sum_{i=1}^{N} X_{2i}^-$$

A study of the software implementation of the method showed certain shortcomings:

– not in all cases possible to compensate for typical QRS-T complexes,

– selection of 4 coefficients is complicated and takes a long time.

It is proposed to use the a single factor for what it is expedient for each of the cardiac complex to form mono impulse (monopulse). QRS complexes detection algorithm is based on the ranking procedure MSM (MaxSubMin), performed in a sliding window [6]. This procedure just creates a monopulse signal. MSM procedure is to perform three sequential steps:

finding the maximum value of a discrete reference ECG signal in a sliding size 2s + 1 window;

finding the minimum value of the discrete reference ECG signal in a sliding size 2s + 1 window;

subtracting the minimum value from the maximum value.

Formally MSM procedure is written as follows:

$$y_{\max}(t) = \max(x(t-s),\ x(t-s+1),\ ...,\ x(t-1),\ x(t),\ x(t+1),\ ...,x(t+s-1),\ x(t+s));$$
$$y_{\min}(t) = \min(x(t-s),\ x(t-s+1),\ ...,\ x(t-1),\ x(t),\ x(t+1),\ ...,x(t+s-1),\ x(t+s));$$
$$MSM(t) = y_{\max}(t) - y_{\min}(t).$$

Examples of the formation of MSM procedure of monopulse signal and subsequent integration into the sliding window (MSMI) are shown in Figure 2. The blue line represents the input ECG signals, and the red line represents a monopulse signal. Monopulse signal can uniquely detect the QRS complexes in all four cases (ECG signals with high-amplitude T wave, ECG signals with the drift of isoline, ECG signals from motion artifacts, ECG signals with negative QRS complexes).

Figure 3 procedure MSMI window size is 11 samples (s = 5), the size of the integration window 21 samples (frequency for sampling ECG signals fd = 500 samples per second).

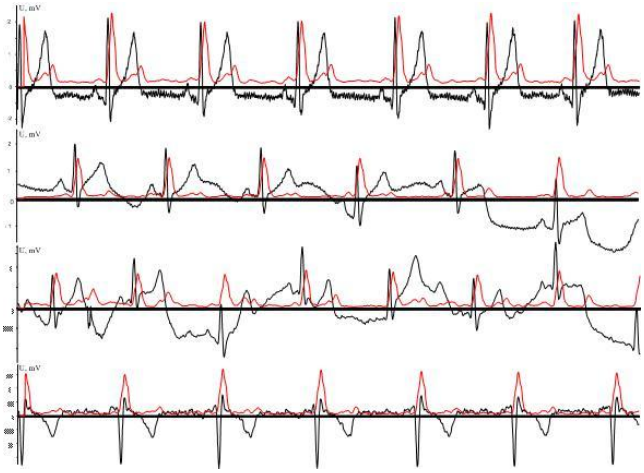

**Figure 2**

The combination of methods described above allowed to create a method of differential detection of ECG complexes

$$Z(t) = MSMI1(t) - K \cdot MSMI2(t),$$

where K is a tuning factor, which is set at the beginning of the research.

The structure illustrating the proposed method, shown in figure 3.

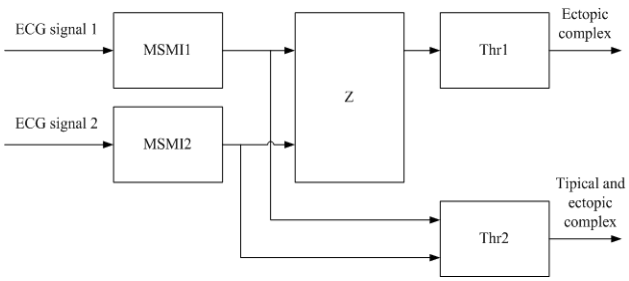


**Figure 3**

Example of the formation of pulses corresponding to ectopic complexes, shown in figure 4 (output Z).

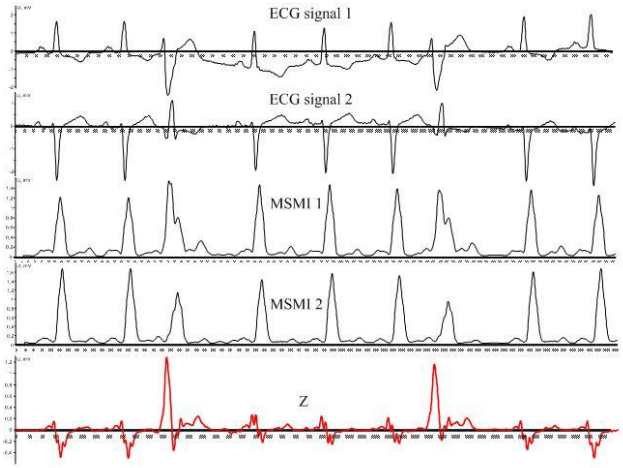


**Figure 4**

The developed method of differential detection of the QRS complexes is simple and has high performance, it can be implemented in real time. It does not use complex algorithms based on pattern recognition (recognition of many classes with their further classification into normal and ectopic).
Testing the developed method on signals from MIT-BIH Arrhythmia Database showed that the probability of correct detection of QRS complexes (sensitivity), even without pre-filtering is 0,97-0,98.
The application before the procedure MSMI the «hard» filtering with a bandwidth of 2-30 Hz, and the introduction of adaptive threshold improves the probability of correct detection of QRS complexes to 0.99 (when you test on the same signals). The characteristics of detection of ectopic complexes are about the same.
Method recommended for use in the system «WebMulti-Medic» with the aim of improving the quality of ECG-diagnosis.

## Results

For analysis of postoperative cognitive dysfunction using stabilographic monitoring of patients operated on for chronic cholecystitis, the study on 29 patients operated at the Penza clinical hospital № 6 named after G. A. Zakharyin.
Studies were conducted with the approval of the Local ethics Committee, and written consent from each patient for the surgery, anesthesia and research.
The choice of patients contingent for the study was determined by the fact that in laparoscopic cholecystectomy a direct impact on the musculoskeletal system is considered to be minimal compared to other interventions, which allows to put the patient on his feet in the first day of the postoperative period.
All patients were divided into 2 groups: group 1 (23 patients in the perioperative period received antioxidant therapy with mafusol and cardioksipin); control group 2 (6 patients, the perioperative period, this therapy was not used).
The surgery was performed under endotracheal anesthesia (a common method of anaesthesia induction and supporting anesthesia with nitrous oxide).
Stabilographic examination of patients was performed before surgery, 24 hours and 48 hours after surgery. The majority of patients were discharged to outpatient treatment within 3-4 days.
In addition to the common in the clinic of the research was determined stabilographic parameters: X is the average position of the center of pressure (CD) on the X-axis (mm); Y – middle position CD along the Y-axis (mm); V – average speed of displacement of the CD (mm/s); S – area of statokinesigram ($mm^2$) [7] (figure 5).
Revealed the difference of the indices of stabilography: in the control group, the rate of displacement of the center of pressure (V) and area of the stabilogram (S) have a larger spread of values for all modes of study (with open and closed eyes) than in the group of patients who received antioxidant therapy in the perioperative period.

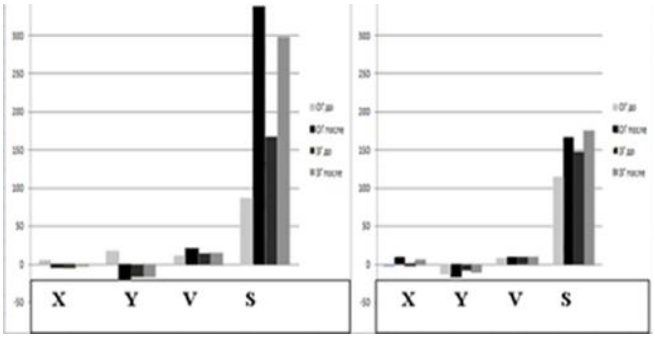


Figure 5

In the course of further studies, we studied in more detail the dynamics of changes in the stabilographic parameters in 120 patients in the perioperative period with laparoscopic cholecystectomy, as a result, a method was patented to reduce the anesthetic risk during laparoscopic cholecystectomy [7].

## Discussion

To identify cognitive disorders in clinical practice most commonly used short scale assessment of mental status (MMSE) proposed by M. F. Folsteinи co-authors in 1975 and represents a short questionnaire of 30 items, widely used for the primary assessment of cognitive function and screening of their violations. The diagnostic sensitivity of this technique is not absolute, but is too selective.
Another method for neuropsychological evaluation of cognitive disorders that have a higher sensitivity in comparison with the test ME is MoCA test – the Montreal scale assessment of cognitive disorders (2004) [1].
However, these techniques have a substantial component of subjectivity offer only the qualitative characteristics of the patient.
The sensitivity of the stabilometric method and the quality of information allowed to use this method to determine the current functional state of the patient, the researcher receives information about static and locomotor functions of the patient which cannot be obtained by any other means [8].
In this regard, there is reason to assume that the used during anesthesia medication and other means, affect the static and locomotor functions of the patient and can be measured quantitatively, which may serve as an objective safety criteria conducted anesthesia.
Another important and objective criterion for assessment of postoperative condition of the patient can serve as the parameters characterizing the violation of his heart rate, especially the presence of dangerous ectopic ventricular complexes in the ECS.
Therefore, we believe a promising integrated research stabilographic and cardiological criteria for the assessment of anesthesia that is given undeservedly little attention, by both domestic and foreign researchers.

## Conclusions

Thus, the results of the conducted research we can draw the following conclusions.

1. Instrumental method of monitoring based on computerized of stabilography and channel ECG diagnosis system «WebMultiMedic» can serve as a complementary tool of the anesthesiologist in the optimization of General anesthesia in patients during laparoscopic cholecystectomy.
2. The modernization of the ECS channel analysis system «WebMultiMedic», namely, the introduction of differential detector complexes of the ECS, allows high accuracy to detect PVCS and assess the risk of sudden cardiac death.
3. According to the study most informative stabilographic parameters are the velocity of center of pressure on the platform and the area of the stabilogram. It is important that in the control group, the variation rate of displacement of the center of pressure and area of the stabilogram were significantly greater than in the group of patients who received antioxidant therapy in the perioperative period (for all modes of study).
4. The results of these studies quantitatively confirm the feasibility of the use of stabilography as a tool to optimize anesthesiological treatment of patients with laparoscopic cholecystectomy.
5. The research results confirm the feasibility multidiagnostic survey and research of all groups of postoperative patients with a view to detection of postoperative cognitive disorders.

## References


[1] Postoperative cognitive dysfunction and the principles of cerebroprotective in modern anesthesiology: a training manual for physicians / ed. by A. M. Ovezova. – Moscow, 2015. – 76 c.

[2] V.V. Istomin, T.V. Istomina, A.V. Kireev and A.I. Safronov, "Methodical software of the system for remote multidiagnostic and rehabilitation of patients after hip replacement," Scient. and Tech. Bull. of the Volga, 1, 113 (2011).

[3] T.V. Istomina, A.V. Kireev, A.I. Safronov, V.V. Istomin and T.V. Karamysheva, Patent for useful model number 122009. Stabilometric simulator, (Russian Federation, 2011).

[4] Istomina T. V., Filatov I. A., Safronov A. I., Istomin V. V., Karpitskaya S. A., and others. Modern equipment for remote Multidiagnostic and rehabilitation of patients with postural deficits // «XXI century: results of the past and challenges of the present plus»: a scientific Periodical. – Penza: Publishing house PenzGTU, 2013. – №09(13). T.1. – C. 64-70.

[5] Patent № 1616600 of the USSR. Detector ventricular extrasystoles / T. V. Istomina, L. Yu. Krivonogov, Yu.V. Polubabkin; publ. 30.12.1990, Newsletter № 48.

[6] Krivonogov L. Yu. System for electrocardiographic diagnosis of critical conditions in terms of the free activity of the patients. Diss. ... Ph. D.: Penza, 2017.

[7] Patent № 2594976 of the RF. A method of reducing anesthetic risk during laparoscopic cholecystectomy» Safronov A. I., Kireev V. A., Vasil'kov V. G., Karpitskaya S. A. egistered in State register of inventions of the Russian Federation of 28 July 2016.

[8] Skvortsov D. V. Stabilometric study: a brief guide / by D. V. Skvortsov, M.: Mask, 2010. — 172 c.