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New method of processing measurement results of tissue oxygen saturation abnormalities

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Abstract. The necessity of monitoring the oxygen status of human tissues to detect various diseases at different stages is substantiated. A noninvasive intelligent blood filling control complex for lower limb ischemia using a multisensory system based on optical sensors and machine learning methods is presented. The results are presented, indicating the possibility of automated detection of deviations from the norm of the parameters of blood filling of the extremities.

Keywords: intellectual complex, oxygen status, laser radiation, pulse, lower limb ischemia, machine learning

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Новый метод обработки результатов измерений нарушений кислородного насыщения тканей

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Аннотация. Обоснована необходимость контроля кислородного статуса тканей человека для выявления различных заболеваний на различной стадии. Представлен неинвазивный интеллектуальный комплекс контроля кровенаполнения при ишемии нижних конечностей с использованием мультисенсорной системы на основе оптических датчиков и методов машинного обучения. Представлены результаты, свидетельствующие о возможности автоматизированного выявления отклонений от нормы параметров кровенаполнения конечностей.

Ключевые слова: интеллектуальный комплекс, кислородный статус, лазерное излучение, импульс, ишемия нижних конечностей, машинное обучение

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Introduction

The deterioration of the ecological state of the environment has led to a number of negative factors. One of them is associated with the deterioration of people's health. Therefore, personalized monitoring of human health is increasing every year in most countries of the world [1-4]. Among the methods for solving these problems, the greatest preference is given to non-invasive [1-9]. Diagnostics with their use, especially in personalized medicine, is becoming increasingly relevant all over the world [2-4, 6-8, 10-12]. Among noninvasive methods, various optical devices that do not violate the integrity of tissues and structures of the human body are most in demand [2-4, 6-8, 10-15]. Their main advantages are ease of use, high performance and, most importantly, the ability to perform diagnostics outside of a medical institution at any time without limiting the number of applications [1, 3, 4, 6-8, 11-13, 16]. One of the significant directions is the development of optical methods for monitoring blood flow in human limbs using a multichannel spectrum analyzer [17]. Abnormalities in the state of blood flow in the vessels of the extremities detected by optical methods may be associated with the development of dangerous pathologies, such as diabetes mellitus, atherosclerosis and others. Methods based on nuclear magnetic resonance, which are used to confirm many of the identified factors by optical methods, can be used only in stationary laboratories [18-21].

In the modern world, more than 200 million people suffer from lower limb ischemia of varying severity. Atherosclerosis is the primary factor of disability of the population of the Russian Federation. It is in Russia that the highest rate of amputations in atherosclerotic pathology of the lower extremities. Every year, about forty thousand patients in the Russian Federation undergo amputation of the lower extremities, in which the mortality according to various data varies from 10% to 49%. In the Russian Federation, ischemia of the lower extremities of varying severity is currently registered in 1.5 million patients. Therefore, the diagnosis of such vascular pathologies at various stages is one of the most significant tasks in modern medicine.

The purpose of this study is to create a prototype of an intelligent diagnostic optical system for non-invasive monitoring of disorders of oxygen saturation of human lower limb tissues. The method is based on a combination of using machine learning methods and optical methods for registering spectra using a multichannel analyzer having operating wavelengths in the range from 410 to 940 nm. Groups of subjects with different risks of blood supply disorders were formed using a mathematical analysis of the results obtained using the principal component method.

Materials and Methods

A non-invasive intelligent complex for optical analysis of the oxygen status of human tissues in lower limb ischemia consists of two modules. The first, the sensor unit, is a set of chips that consists of three sensor devices. Multispectral sensors can be used for spectral identification in the range from visible to infrared. Each of the three sensor devices has 6 built-in optical filters, the spectral response of which is determined in the range from 410 to 940 nm with a pulse duration at the level of half the amplitude of 20 nm. The second, the software block, is presented in the form of a mathematical model for processing the results obtained [22]. On the screen of a personal computer, we receive measurement results, which are presented as a multidimensional array of information. At the output, we have a diagram of the change in the readings of optical sensors over time. Using machine learning methods and principal components, the result has the form of a "point" in two-dimensional space. This method of displaying the results is especially convenient for grouping groups of subjects. derivatives. diabetes, atherosclerosis and others.

This experiment was conducted on the basis of the Almazov National Medical Research Center of the Ministry of Health of the Russian Federation. The study involved a man aged 67 with a diagnosis of diabetes mellitus. The man has an affected left leg and a relatively healthier right one. Measurements were carried out on both legs. The location of the optical system was the lower part of the shin. diabetes, atherosclerosis and others.

The optical system readings were recorded in three time intervals. First, the condition of rest for 1 minute 40 seconds in a standing position. This was followed by the patient performing low-intensity physical activity (3 metabolic units (MET)) within 5 minutes. The final stage, the process of recovery of the subject after performing load tests for 1 minute 40 seconds. Measurements were carried out once for a healthy leg and twice for the affected one with an interval of 10 minutes for complete recovery of the body. diabetes, atherosclerosis and others.

Physical exertion causes significant changes in the blood filling of the extremities and disorders in hemodynamics, as a result of which pathophysiological conditions can be more pronounced, the identification of which helps to diagnose hidden diseases, for example, diabetes mellitus, atherosclerosis and others.

Results and Discussion

A mathematical analysis of the measurement results was performed, which were recorded by the optical system, healthy and affected lower extremities of the subject with diabetes mellitus.

Various responses of the patient's limbs to physical activity were obtained, the results of the ranking were visualized, which made it possible to identify hidden patterns in the change in blood filling of the limbs according to the indications of optical sensors at various points in the experiment.

As a reference, measurements were made from the patient's healthy leg at rest in a standing position, when performing low-intensity physical activity (3 metabolic units), as well as during recovery.

Fig. 1 shows the measurement results of the patient's healthy leg. It can be seen from the graph that at rest in the standing position, as well as when performing a load, the sensor readings vary in the same range of values, but in the process of recovery, the indicators are lowered.

Then the optical system was moved to the other leg in the same way as the previous one. Next, the affected leg was measured twice with an interval of 10 minutes for the full recovery of the body after the previous physical activity. The sensor remained in the same place throughout the recovery, as well as the subsequent experiment.

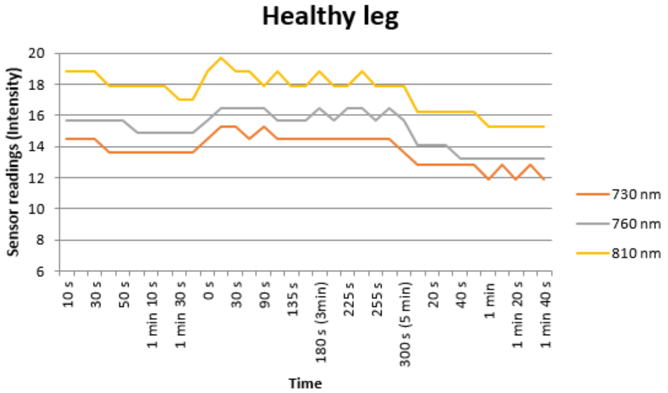

Fig. 1. Sensor readings (intensity) depending on the time at rest, physical activity and the process of restoring the patient's healthy leg for wavelengths of 730,760, 810 nm

The measurement results of the affected leg are shown in Figs. 2 and 3. In comparison with the "Healthy Leg" graph, we can trace a clearly different trend in changing sensor readings. Firstly, the range of values at rest is several values lower in the affected leg than in the healthy one. Secondly, with the beginning of physical activity, we see a sharp jump in readings up, similarly, at the end of the load, a sharp decline in values.

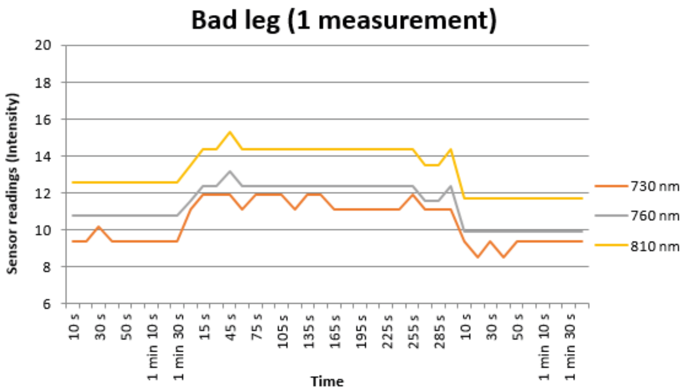

Fig. 2. Sensor readings (intensity) depending on the time at rest, physical activity and the recovery process of the patient's diseased leg for wavelengths of 730,760, 810 nm (1 measurement)

In addition, there is a difference in the graphs "Sore leg (1 measurement)" and "Sore leg (2 measurement)", which may be caused by the registration of measurements after the onset of the state of "acute training", the appearance of which may occur after several load tests in a row

According to the data obtained above, it can be said that a small shift of the sensor may occur at the beginning of the load. Distortions in the data caused by the sensor shift are proposed to be detected and removed using statistical data processing methods and machine learning methods. In addition, for the purpose of more rigid fixation of the optical system, options for changing the design of the sensor, as well as other types of fixing the device to the measurement site, will be considered.

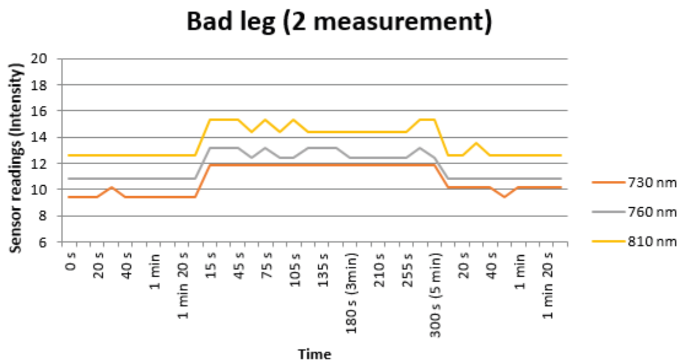

Fig. 3. Sensor readings (intensity) depending on the time at rest, physical activity and the recovery process of the patient's diseased leg for wavelengths of 730,760, 810 nm (2 measurement)

Conclusion

The obtained results of the study reflect the relevance of the methodological approach to solving the problems of non-invasive control of human health and performance, and also indicate the possibility of intelligent automated detection of violations of oxygen saturation of tissues with ischemia of the lower extremities of a person and allow medical personnel to make a preliminary decision on the presence or absence of pathology.

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