Wearable devices of multimodal optical diagnostics of microcirculatory-tissue systems: application experience in the clinic and Space

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Microcirculatory-tissue systems (MTS) of the human body are the smallest functional unit of the vascular system, in which microvessels are in close relationship with the surrounding tissue and regulatory elements. Violations in the MTS play a key role in the pathogenesis of various diseases complications and for this reason, their timely diagnosis is the subject of extensive research. At present, there is a surge of interest in wearable electronic diagnostic devices, because daily monitoring of parameters (for example, MTS parameters) promises a new quality of diagnostics. One of the first developments of wearable devices for estimating MTS parameters is the analyzer "LAZMA PF" (LAZMA Ltd, Russia), which combines a multimodal approach, namely, consisting of 2 channels - laser Doppler flowmetry (LDF) and fluorescence spectroscopy (FS). The purpose of this work is to demonstrate the successful experience of using these devices both in clinical practice and in the conditions of a Space experiment.

As one of the examples of the successful use of these wearable devices in the form of a distributed system on the body of endocrinological patients, the age norms of blood microcirculation parameters for the fingers and forearms, as well as their characteristic values for patients with type 2 diabetes, were obtained. Based on the synthesized decision rule, an algorithm for the diagnostic method has been developed that allows detecting 4 types of pathological changes in the blood microcirculation system - stasis, ischemia, arterial hyperemia, venous congestion, which allows doctors to objectively use these devices to assess perfusion-metabolic disorders in the biological tissues of patients' limbs.

Another example of the use of these devices in endocrinology is the study of the effect of pregestational type 1 diabetes on the state of MTS in patients at different stages of pregnancy. This study is the first to show the combined use of LDF and FS together with glucose variability monitoring to assess vascular function and oxidative metabolic status in pregnant patients with pregestational type 1 DM. The development of this work is seen in the comparison of LDF and FS monitoring data of patients with their glucose variability monitoring data to analyze the possible effect of diurnal blood glucose changes on oxidative metabolism and blood microcirculation.

These devices were also used to evaluate the effectiveness of rehabilitation measures in patients who underwent COVID-19. This pilot study has shown a tendency for the amplitudes of active rhythms to increase after the acute phase of the coronavirus, but the overall level of perfusion decreases, which may indicate that the patients' body seeks to repair biotissue not by increasing arterial blood flow but by redistributing it into the nutritive part. The use of these devices during both the active phase of the disease and the period of recovery of the body, allows one to determine this period more accurately, as well as control the effectiveness of both treatment and rehabilitation.

Another illustrative example of using wearable devices is assessing the effect of hypo-and hyperventilation yoga breathing exercises on the parameters of peripheral blood flow and their relationship with parameters of spirometry and gas analysis. The obtained results shown, that performing full breathing leads to a statistically significant increase in the microcirculation index, regardless of the respiratory rate. The obtained results of the relationship between the parameters of microhemodynamics and gas analysis can be useful in studying the features of the mechanisms of oxygen delivery to biological tissues in various modes of respiration. Wearable analyzers allow us to develop an instrumental method for monitoring the performance of full-fledged breathing exercises and their effectiveness in rehabilitation.

An example of the successful application of new multimodal devices was a Space experiment "LAZMA" aboard the ISS during 20 visiting expedition (December 8-20, 2021). The main goal of this Space experiment was study of tissue respiration processes (oxygen utilization by tissues) and microcirculatory blood flow in human skin under zero-gravity conditions. For the first time, a technique has been developed for measuring MTS in the limbs of cosmonauts during the period of acute adaptation to microgravity conditions and readaptation after the completion of a Space flight. Obtaining the most important physiological information in real time under conditions of zero-gravity will provide completely new data on the physiology of the MTS in humans under conditions of orbital flight.

Thus, the data on the state of the MTS of the human body recorded with wearable multimodal devices make it possible to assess the relationship and dynamics of oxygen utilization more comprehensively and reliably by tissues in a variety of diagnostic tasks.