MULTIPARAMETER OPTICAL DIAGNOSTICS OF MICROCIRCULATORY-TISSUE SYSTEMS: METHODS AND TECHNICAL MEANS

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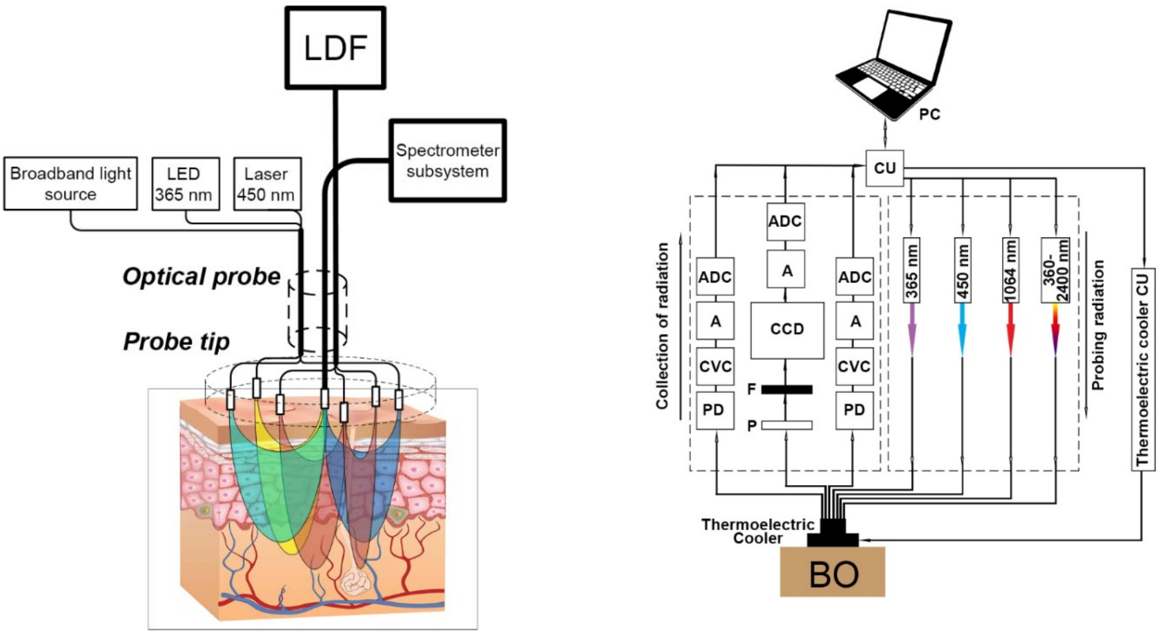
Abstract

In the last decade, there has been a steady increase in the interest of researchers in the problems of non-invasive research of microcirculatory-tissue systems (MTS). This is due to the essential role of blood microcirculation in the pathogenesis of various diseases (in particular, diseases of the rheumatological and endocrinological profiles). A modern trend in the development of optical biomedical diagnostics is a multiparametric approach when various optical (and sometimes additionally other) research methods are combined in one diagnostic technology. This allows one to obtain highly efficient diagnostic tools for rheumatology, endocrinology, surgery, oncology, neurology, and other areas of medicine, where it is necessary to determine the parameters of the perfusion-metabolic status of tissues.

The aim of this work was to scientifically substantiate and develop a methodology for multiparametric optical non-invasive diagnostics (mOND) to assess the functional state of the microcirculatory-tissue systems of the human body with the development of metrological support of methods and technical means that contribute to improving the quality of optical non-invasive diagnostics and its wider implementation in clinical practice.

To solve the research problems, a systematic approach was used to develop a methodology for the synthesis of mOND for assessing the functional state of MTS in various diseases. A method for assessing angiospastic and microcirculatory [1] disorders in rheumatic diseases and a method for assessing microcirculatory-metabolic disorders in MTS of the lower extremities in diabetes mellitus [2] were developed. Also in this work, methods were developed for assessing the state of the MTS of the human body under various conditions, such as sports and physiological stresses [3], the provision of physiotherapeutic effects, during minimally invasive surgical interventions [4]. The developed methods are based on the combined application of several widely used methods of optical non-invasive diagnostics, such as laser Doppler flowmetry(LDF), diffuse reflection spectroscopy (DRS), fluorescence spectroscopy (FS), etc.The scheme for implementing the multiparametric optical measurements is shown in the Fig. 1a.The block diagram of one of the variants of the device for assessing the functional state of the MTS of the human body on the basis of multiparametric optical diagnostics using 3 methods of OND (LDF, FS and DRS) is shown in the Fig. 1b.



a) b)

Figure 1: *The scheme for implementing the multiparametric optical measurements (a)*

and the block diagram of the device for assessing the functional state of the MTS (b).

The LDF optical-electronic system is made in the form of two identical channels for recording the Doppler signal and includes a laser radiation source with a wavelength of 1064 nm connected to a driver that sets the power supply, and an

optical-electronic system for recording secondary optical radiation, consisting of photodiodes (PD) with optical filters, connectedin pairs with the Doppler signal forming unit, consisting of current-to-voltage converters (CVC), signal amplifiers (A) and analog-to-digital converters (ADC). Each channel has a sequential signal conversion.

The FS and DRS channels include sources of fluorescence excitation with wavelengths of 365 and 450 nm, connected to drivers that set the power supply, and a broadband radiation source, a polychromator (P), a set of replaceable light filters (F), and a CCD radiation detector. The polychromator is built according to the Czerny-Turner scheme with a flat diffraction grating.

The channels are controlled by a common control unit (CU), which is an PLD with a binding connected through an interface with a personal computer (PC). The CU controls the operation of the emitters (supplying control signals to their drivers) and turning on the broadband radiation source. Laser emitters with wavelengths of 450 and 1064 nm, a light-emitting diode with a wavelength of 365 nm and a broadband radiation source with a wavelength range of 360 ... 2400 nm are used as sources of primary optical radiation. The light from these sources is transmitted through a fiber bundle to the area of study of the biological object (BO). Fluorescence, diffuse reflectance, and Doppler signals are received by closely spaced receiving fibers. If it is necessary to conduct temperature tests through the CU, an additional temperature exposure channel is connected, built on a thermoelectric cooler with its own control unit, which allows one to change the polarity of the supply voltage. This channel is used to carry out a functional temperature tests in the range of 5-42 °C.

The user communicates with the control unit through a specialized program installed on the PC.

Approbation of the developed methods was carried out on the basis of 3 Departments of the Orel Regional Clinical Hospital (Orel, Russia). The reliability of the results obtained has been confirmed by numerous clinical observations of more than 200 patients.

The results of the work can be extended to other areas of medicine, for example, in the direction of improving methods of optical biopsy in minimally invasive surgery, rheumatology, endocrinology, otolaryngology, dermatology, neurology and other areas of medicine. The introduction of mOND into wearable devices (fitness bracelets, gadgets) for long-term monitoring (daily or during sleep, tracking of circadian biorhythms) and monitoring in vivo (and not only in a hospital) also has great diagnostic potential.

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