Study of features of the microcirculatory-tissue systems reactions to different functional tests by optical non-invasive diagnostic methods

Introduction

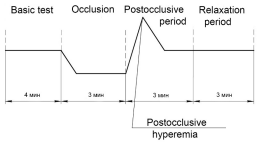
Microcirculatory system disorders play a key role in the pathogenesis of various diseases, such as rheumatological profile diseases or diabetes complications. Various non-invasive optical technology, in particular, well-proven methods of laser Doppler flowmetry (LDF) and fluorescence spectroscopy (FS) are used to assess the state of microcirculatory-tissue systems (MTS). Complex approach, involving simultaneous use of several diagnostic technology during the functional tests, is the most informative.

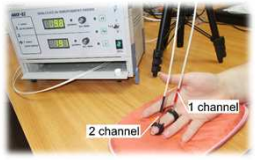
The aim of research

To analyze different reactions of human MTS to various functional tests using laser Doppler flowmetry (LDF) and fluorescence spectroscopy (FS). Experimental study consisted of two parts and included study of MTS reactions to occlusion and heating tests.

Study of MTS reactions to occlusion test

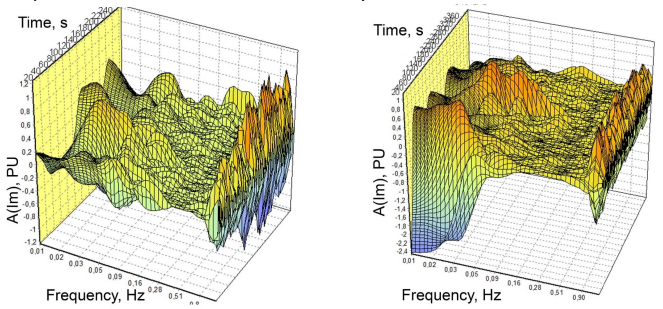
Experimental method and equipment





Experimental studies were carried out using dual-channel laser analyzer of capillary blood flow "LAKK-02" (SPE "LAZMA", Russia). In this device probing of biological tissue carried out at a wavelength of 1064 nm. The study included registration of a base test of LDF-gram for an 4 minutes-period, holding the occlusion test with a cuff pressure of 220 mm Hg for a 3 minutes-period and recording the basic test for a 6 min-period.

Each registred LDF-gram was subjected to adaptive wavelet analysis by the LDF 3.0.2.384 program, which performs a continuous wavelet transform and utilizes the complex-valued Morlet wavelet as an analytic wavelet.

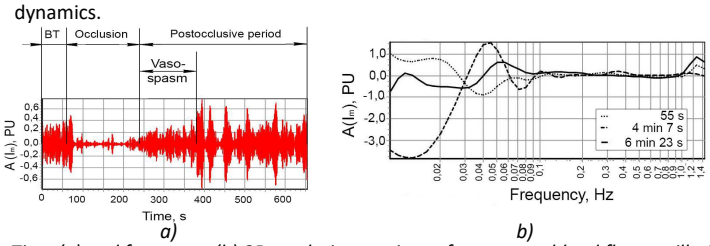


a) *b)*

Example of LDF-gram 3D-analysis before (a) and after (b) conducting occlusion

Experiments were performed on **28 volunteers and 1 patient** diagnosed with Raynaud's syndrome.

Analysis of the data revealed statistically significant differences between the amplitudes of the blood flow oscillations in the initial and postocclusive periods. In addition, the proposed method allows to evaluate the adaptation process of MTS in dynamics.



a) *b)*

Time (a) and frequency (b) 3D-analyzing sections of cutaneous blood flow oscillations

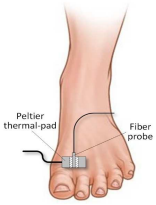
Analysis of the data obtained on the patient revealed that after occlusion the amplitude of oscillations in the cardiac frequency range remain at a reduced level, which may indicate a spasm of resistance vessels. Immediately after the cessation of occlusion there was a sharp increase in myogenic tone, which may indicate vasoconstrictor processes.

Study of MTS reactions to heating test

Experimental equipment

Experimental studies were carried out using laser multifunctional complex "LAZMA-D" (SPE "LAZMA", Russia) and the "LAZMA-TEST" device. The analyzer "LAZMA-D" records in combined form the method of LDF (with a probing wavelength of 1064 nm) and the method of FS with two wavelengths of excitation (365 nm and 450 nm) in approximately the same diagnostic volume (≈ 2-3 mm³). To provide thermal effects the "LAZMA-TEST", designed for functional heating (5-50°C) and electro-stimulation tests, was used.

Experimental study

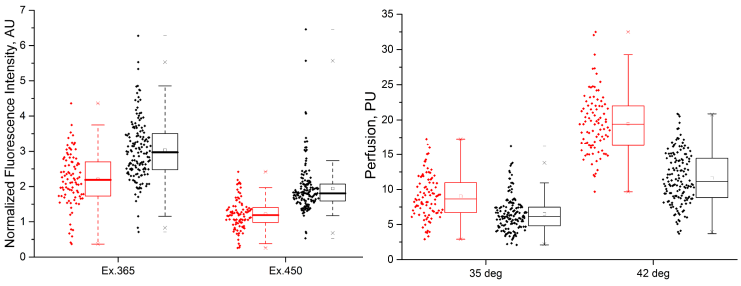


Location of the optical sensor

Research method using temperature tests

№ of experimental stage	1	2	3	4
Name of stage	Basic test	Local cold test	Local heating test	Local heating test
T°C	Body temperature	25	35	42
Duration	4 min	4 min	4 min	10 min

Experiments were performed on **76 patients** diagnosed with diabetes and **46 volunteers**. Experimental studies were carried out on the dorsal surface of the foot. The idea of the research was the implementation of provocative actions on blood flow through local heating tests (35&42°C).



a) *b)*

- control group; - patients.

Averaged normalized fluorescence (a) and index of microcirculation (b)

The results of the study revealed that fluorescence intensity for patients is larger in comparison with the control group. This increase in fluorescence can be due to the accumulation of advanced glycation end products that may initiate expression of collagen genes and other proteins of the capillary membrane and skin.

At the same time, rate of the perfusion and nutritive blood flow upon heating to 35 and 42 degrees for patients are statistically smaller, possibly indicating disorders in the function of precapillary sphincters.

Conclusion

The possibility of an adaptive wavelet transform to qualitatively assess the dynamics of change in the amplitude of the oscillations of the skin blood flow in the investigated frequency ranges while analyzing the LDF-grams is shown. Studies on patients of endocrinology and rheumatology profiles show that the proposed approach in the form of combined optical diagnostics of the state of the microcirculatory-tissue systems and analysis of peripheral blood flow oscillations show a high capacity for the analysis of the functional state and forecasting the development of pathological processes.

Acknowledgements

Thanks to Prof A.I. Krupatkin, Dr V.V. Sidorov, Prof E.U. Rafailov, Dr K.S. Litvinova and all members of Biomedical Photonics Instrumentation Research Group for their help in this work. Special thanks are extended to doctors Alimicheva E.A., Masalygina G.I. and Muradyan V.F. of "Orel Regional Clinical Hospital" for providing useful advice and help. Thanks to all patients and volunteers for their participation in this work. This work were supported by the Russian Foundation on Innovations U.M.N.I.K.

E.V. Zharkikh

Biomedical Photonics Instrumentation Group, Scientific-Educational Centre of "Biomedical Engineering",
Orel State University named after I.S. Turgenev, Orel, Russia

Orel State University named after I.S. Turgenev
http://oreluniver.ru

Contacts:
E-mail: *loread@mail.ru*
+79534740686

SCIENTIFIC-EDUCATIONAL CENTER BIOMEDICAL ENGINEERING
http://www.bmecenter.ru/en