

Complex analysis of metabolic and hemodynamic processes in patients with diabetes mellitus using optical non-invasive diagnostic methods

E.Zharkikh¹, M.Filina¹, V. Dremin¹, E.Potapova¹, I.Makovik¹, E.Zherebtsov¹,

A. Zherebtsova¹, A. Dunaev¹, V. Sidorov², A. Krupatkin³

¹Biomedical Photonics Instrumentation Group, Scientific-Educational Center of "Biomedical Engineering", Orel State University named after I.S. Turgenev, Orel, Russia

²SPE "LAZMA" Ltd, Moscow, Russia

³Priorov Central Research Institute of Traumatology and Orthopaedics, Moscow, Russia

Introduction

Early diagnosis of diabetes mellitus and monitoring the effectiveness of treatment of diabetes mellitus are among the most critical issues in modern health care. One promising direction in modern clinical practice is the diagnosis of the functional state of the biological tissue of patients lower limbs, allowing the identification of emerging trophic disorders at earlier stages. Today, the combined use of various optical non-invasive methods is promising and informative for complex diagnosis of complications in diabetes, for example, laser Doppler flowmetry (LDF), fluorescence spectroscopy (FS) and diffuse reflectance spectroscopy methods (DRS).

The aim of research

To evaluate the possibilities of combined use of optical diagnostic methods for the analysis of metabolic and hemodynamic processes in the study of the lower limbs in patients with diabetes.

Experimental method and equipment



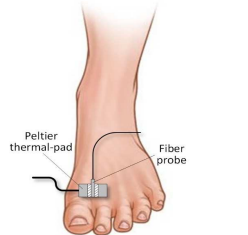
Experimental equipment

Experimental studies were carried out using laser multifunctional complex "LAZMA-ST" (SPE "LAZMA", Russia), which consists of two devices: the analyzer "LAZMA-D" and the block "LAZMA-TEST". 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 respectively) in approximately the same diagnostic volume ($\approx 2-3 \text{ mm}^3$). To provide thermal effects the block "LAZMA-TEST", designed for functional heating (5-50°C) and electro-stimulation tests, was used.

Experimental study

Research method using temperature tests

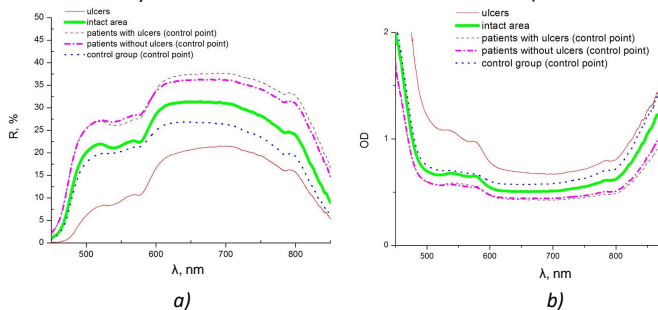
N ^o of experimental stage	1	2	3	4
Name of stage	Basic test	Local cold test	Local heating test	Local heating test
T ^o C	Body temperature	25	35	42
Duration	4 min	4 min	4 min	10 min



Location of the optical sensor

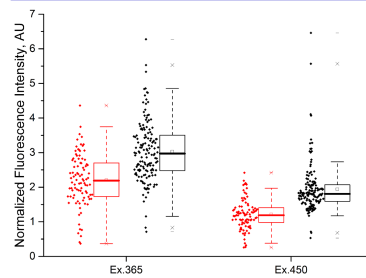
Experiments were performed on **76 patients** diagnosed with diabetes and **46 volunteers**. Experimental studies were carried out on the dorsal surface of the foot. The idea of the research was the implementation of provocative actions on blood flow through local heating tests (35&42°C).

Before the beginning of each study at the specified point registration of the spectra of skin diffuse reflection was carried out by a compact spectrometer "FLAME" (Ocean Optics, USA). In addition, for patients with visible trophic disorders such as ulcers, spectra were recorded directly at ulcers and at one centimeter from ulcers (at the intact region).



Averaged reflectance (a) and skin optical density (b) spectra

Results and Discussion

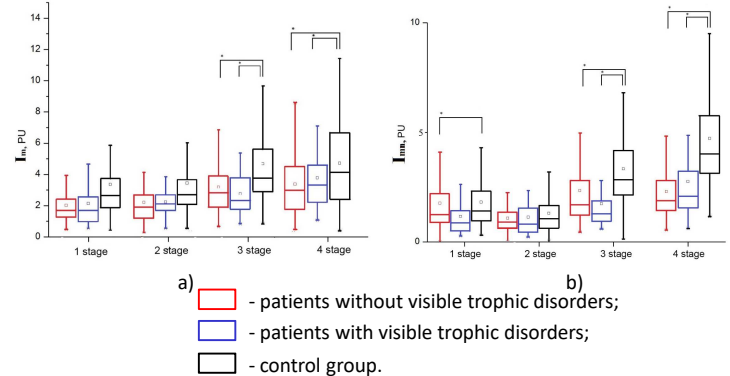


The results of the study revealed that fluorescence intensity for patients is larger in comparison with the control group. This increase in fluorescence can be due to the accumulation of advanced glycation end products that may initiate expression of collagen genes and other proteins of the capillary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

Red box - control group;
Black box - patients.

Normalized fluorescence intensity

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.



a) Red box - patients without visible trophic disorders;
Blue box - patients with visible trophic disorders;
Black box - control group.

* - statistically significant differences of values of indicators in groups of patients relative to control group with $p < 0.05$ for the Mann-Whitney test

Averaged index of microcirculation (a) and nutritive blood flow (b)

To study ulcerative processes CDR-ratio was calculated at wavelengths of the oxyhemoglobin absorption (540 and 578 nm). Highest blood circulation was observed in patients with focal disorders. Erythema index for patients without ulcers was higher than that of volunteers from the control group, which may indicate the presence of disorders in the peripheral circulation.

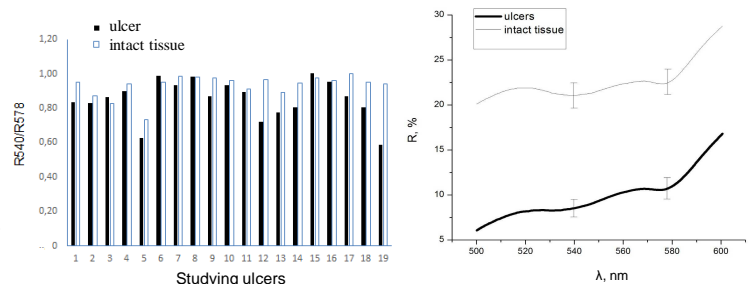


Chart relations R540/R578 to ulcers and intact region in patients

Averaged skin diffuse reflectance spectra of patients

Conclusion

The combined use of optical non-invasive diagnostic methods can detect the presence and dynamics of development of trophic disorders in the skin of patients with diabetes mellitus in lower limbs.

Acknowledgements

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