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COMPLEX ANALYSIS OF METABOLIC AND HEMODYNAMIC PROCESSES IN PATIENTS WITH DIABETES MELLITUS USING OPTICAL NON-INVASIVE DIAGNOSTIC METHODS

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ABSTRACT

According to the International Diabetes Federation (International Diabetes Federation - IDF), 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, preventing further complications of diabetes. 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 this work was 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.
To achieve this goal, 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 (≈ 2-3 mm3). To provide thermal effects the block "LAZMA-TEST", designed for functional heating (5-50^{o}C) and electro-stimulation tests, was used. Measurements

were carried out on 76 patients diagnosed with diabetes (53±13 years old) and 46 apparently healthy volunteers (36±11 years old). The study involved registration of changes in blood flow and the fluorescence of biological tissue coenzymes during 4 successive stages: registration of a base test of LDF-gram for a 4 min period, registration of a local cold test (t=25 °C) and a local heating test (t=35 °C) for a 4 min each, registration of a local heating test (t=42 °C) for a 10 min. Thus, the duration of one study on one foot was 22 min. The optical fiber probe was installed on the dorsal surface of the foot on a point located on a plateau between the 1st and 2nd metatarsals. 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). 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.

Registration of the blood microcirculation index (Im) and the IF365 and IF450 fluorescence amplitudes was performed. During the study the oscillation amplitude values for the 5 main frequency ranges were determined: endothelial, neurogenic, myogenic, respiratory and cardiac. Indicators of endothelial (ET), neurogenic (NT) and myogenic tone (MT), bypass indicator (BI) and nutritive blood flow (Imn) were calculated. According to the data of DRS measured spectra curves of the skin diffuse reflection were analyzed. To study the effects of ulcerative processes, the ratio of the diffuse reflection coefficient (DRC) at the absorption wavelength of oxyhemoglobin (540 and 578 nm) was calculated. Erythema coefficient was calculated and analyzed according to the method in which area under the curve of the skin optical density in the spectral range of 510-610 nm was estimated. This method allows quantification of the content of hemoglobin in the skin tissue.

The results of the study revealed that fluorescence intensity for patients is larger in comparison with the control group (3.1 ± 0.9 a.u. vs 2.2 ± 0.8 a.u. and 2.3 ± 1.1 a.u. vs 1.2 ± 0.4 a.u. upon excitation using UV and blue light, respectively). 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 (4.7 ± 2.5 pf.ed. vs 2.8 ± 2.2 4 pf.ed. for 4 phase of the study), possibly indicating disorders in the function of precapillary sphincters.

During the research it was also discovered that the 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 (17.1 ± 11.7 vs 13.3 ± 8.6), which may indicate the presence of disorders in the peripheral circulation.

Thus, 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.

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