Laser Doppler flowmetry and spectroscopy methods in assessment of microvascular and metabolic complications in diabetes

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According to the International Diabetes Federation (IDF), the problem of early diagnosis of diabetes mellitus (DM) and its complications is one of the most acute in modern healthcare. Decreased perfusion, oxygen delivery and consumption are among the most important factors. The skin is easily amenable to research using various optical diagnostic methods that give an idea of the physiology and various pathologies of tissues. In this study a joint application of the laser Doppler flowmetry (LDF), fluorescence spectroscopy and diffuse reflectance spectroscopy methods was suggested. The aim of this work was to investigate the possibilities of optical non-invasive diagnostic methods in determining of microcirculatory and oxygen metabolism disorders in patients with DM.

Experimental studies of healthy volunteers and patients with DM were conducted. Two study protocols were used. The first part of the study involved 4 stages: registration of a basic test of LDF-record 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. During each stage a pair of fluorescence spectra were registered (excitation wavelengths are 365 and 450 nm). The optical 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 centimetre from ulcers (at the intact region). The next part of the study included another sequence of temperature effects. The study was conducted in three stages. Namely, they are follow: registration of the LDF-record and fluorescence signal in basal condition for 8 min, local cooling to 10 °C for 1 min and then local heating to 35 °C for 4 min. Parameter registration was not performed until the achievement of specified temperature. The optical probe was installed into the hole of Peltier element intended for thermal tests. Studies were carried out on the feet in places with glabrous and nonglabrous skin.

The result of the study revealed that the rate of the perfusion upon heating to 35 and 42 degrees for patients are statistically smaller (Im3 = 6.74±2.70 PU; Im4 = 11.89±3.71 PU) compared to control group (Im3 = 9.44±3.28 PU; Im4 = 20.12±4.35 PU), that may indicate insufficient re-regulation of blood-microcirculation system by mechanisms that provide vasodilation. Increased fluorescence intensity in patients in comparison to 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. During the research it was also discovered that the highest blood circulation was observed in patients with focal disorders (66.9 a.u.). Erythema index for patients without ulcers was higher than that of volunteers from the control group (28.7 a.u. vs 13.3 a.u.), which may indicate the presence of disorders in the peripheral circulation.

The proposed approach showed high sensitivity in the detection of peripheral blood flow and oxidative metabolism disorders. The applied methods can be used as additional non-invasive diagnostic methods in endocrinology departments for long-term monitoring of patients' condition.