Application of optical non-invasive methods to diagnose the viability of the lower limb tissues in patients with diabetes mellitus

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Currently, the problem of diagnosis in the early stages of diabetes mellitus (DM) and its complications, which significantly reduces the life level of patients, is acute. One of the prospective directions in the diagnosis of diabetes complications is the study of the functional state of patient lower limbs by non-invasive optical methods. This allows the identification of the emergence of trophic disorders at an earlier stage, and prevention of further complications. Nowadays along with widely used laser Doppler flowmetry method it is informative to use fluorescence spectroscopy method for complex diagnoses of the diabetes mellitus complications [1].

It is known that during prolonged hyperglycaemia advanced glycation endproducts accumulate in the organism, which leads to oxidative stress, and abnormalities in the mitochondrial respiratory chain [2, 3]. These changes may be measured quantitatively by fluorescence intensity of substances involved in the oxygen exchange as well as toxic products of carbohydrate metabolism.

In this connection, the aim of this work was to evaluate the possibilities of simultaneous application of laser Doppler flowmetry and fluorescence spectroscopy methods for identify at an earlier stages of trophic disorders in the skin feet of patients with diabetes mellitus.

To achieve this goal the experimental studies were conducted. The study involved registration of changes in blood flow and the biological tissue coenzyme fluorescence during 4 of the successive stages. The first stage included registration of a base test of LDF-gram for a 4 minute-period. The second and third stages included registration of a local cold test (t=25 ^{o}C) and a local heating test (t=35 ^{o}C) for 4 minutes each. The fourth stage included registration of a local heating test (t=42 ^{o}C) for 10 minutes. Simultaneously with the permanent registration of the perfusion at each stage, a pair of fluorescence spectra at the excitation source with wavelengths of 365 nm and 450 nm were recorded. The light guide probe was brought into contact with the dorsal surface of the foot on a point located on a plateau between the 1st and 2nd metatarsals. All studies were performed in the supine position. After carrying out experiments, LDF-grams of each phase of the study were subjected to adaptive wavelet analysis by LDF 3.0.2.384 program. Experimental studies were carried out by LDF and FS methods using the multifunctional laser noninvasive diagnostic system «LAZMA-ST». System «LAZMA-TEST» was used to provide thermal effects. Measurements were carried out on 76 patients diagnosed with diabetes and 46 apparently healthy volunteers of approximately the same age.

Registration of the blood microcirculation index (I_m) and the I^F_{365} and I^F_{450} fluorescence amplitudes was performed. During the study the oscillation amplitude values for the 5 main ranges were determined: endothelial (A_e), neurogenic (A_n), myogenic (A_m), respiratory (A_r) and cardiac (A_c). These values were normalized to the standard deviation (σ) and the average value of the index of microcirculation (I_m) were also determined. Indicators of endothelial (ET), neurogenic (NT) and myogenic (MT) tone, bypass indicator (BI) and nutritive blood flow (I_{mn}) were calculated to assess the oscillatory component of microvascular tone [4].

Significant differences in all of the above parameters were identified and statistically proved (by Mann-Whitney test, $p < 0,05$) for the group of patients relative to the control group. Experimental studies have shown that diabetic patients have elevated values of normalized

fluorescence amplitudes. Perfusion in response to local heating of 35 and 42 °C was reduced in these patients.

The proposed methodology allows us not only to detect the presence or absence of trophic disorders, but also to determine possible causes, by evaluating adaptation processes during thermal tests and by comparing them with the results obtained in the control group.

Thus the combined use of LDF and FS methods and the use of wavelet transform in the analysis of LDF-grams allows not only to predict the development of trophic disorders and diabetic foot syndrome in the early stages, but also to identify the cause and location of occurrence of these disorders.

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