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EVALUATION OF BLOOD MICROCIRCULATION PARAMETERS BY COMBINED USE OF THE LASER DOPPLER FLOWMETRY AND THE VIDEO CAPILLAROSCOPY METHODS

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ABSTRACT

Non-invasive laser Doppler flowmetry (LDF) and video capillaroscopy (VCS) methods are widely used to study of the blood microcirculation parameters for early diagnosis of various diseases and to monitor the effectiveness of therapeutic measures.
The LDF method allows to assess the dynamics of a tissue structure perfusion by a measurable index of the microcirculation. This is an integrated assessment, which characterizes the general functional state of a tissue, that is a complex disordered biological structure. Spectral analysis of the microcirculation index fluctuations allows to extract with high speed information about modulation of peripheral blood flow within the frequency of cardiac (~1-1.5 Hz), respiratory (~ 0.4 Hz) rhythms and in the frequency range <0.2 Hz. This frequency range is associated with both endothelial, myogenic and neurogenic vascular tone, and as effect of pulsatile transmural pressure of the arteries, which compresses/decompresses the density of capillaries in the dermis, thus modulating the blood volume in the capillary bed.
LDF devices are widely used in medical diagnostics of microvasculature pathologies due to such properties as noninvasiveness, reliability, compactness, speed of acquisition and visualization of the research results. These devices allow visualizing the changes of the microvasculature parameters in the form of the dependence of the time index of microcirculation. The index is calculated by averaging a signal obtained from a specific volume of a biological tissue. This can lead to problems in the interpretation of data, as there is no possibility of analysis of the contribution to the total signal of individual morphological components of biological tissue (individual capillaries).

The VCS method relates to digital microscopy. It is based on registration and analysis of video frames of capillary blood flow of the nail bed. The method requires significant computational power, but it allows extracting the parameters of the capillary blood flow of the individual capillary. This method can be used for verification of data obtained by the LDF-devices, as well as for interpretation of identified features of LDF-grams.

We present the results of simultaneous investigations of changes in tissue perfusion of the distal phalanx of the human hand finger by the LDF as well as changes in capillary blood flow velocity in the nail bed evaluated by the VCS method during arterial occlusion test. Registration of capillary blood flow was carried out utilizing an experimental set-up of capillaroscope, that consists of a high-aperture microscope objective with aperture of 0.12, providing measurements with side illumination, the projection lens and high-speed IDS camera. Video registration rate was 135 fps.

For registration of blood perfusion during occlusion test appropriate hardware and software were developed. Single mode 1064 nm laser was selected as the source of radiation. Optical fibers were used to deliver radiation to the skin and to collect backscattering light. Photosensor scheme used to convert light into current. In the next step, the signal is amplified in a custom electronic board. Analog-to-digital conversion was perfomed by data acquisition board NI USB 6211. Finally, NI LabVIEW environment installed on PC to implement signal processing.

Each experiment included the following procedures: recording of the background level of perfusion (0.5 min); occlusion test (1.5 min); post-occlusion recording (0.5 min). Index of microcirculation was obtained simultaneously with the video capillaroscopy data as discribed above.

The features of LDF-grams related to the detected ones by VCS method reverse blood flow were revealed. It is shown that occlusion (220 mmHg) leads to simultaneous reduction of blood flow in a single capillary from 4 mm/s to 0 mm / sec and index of microcirculation in the distal phalanx of the finger from 300 to 20 perfusion unit. Subsequent gradual increase in the index of microcirculation to 50 perfusion unit with continued occlusion caused a detectable reverse blood flow in the capillary, the speed of which increases gradually from 0 to 0.2 mm/s during the time of registration (40 s). End of the occlusion is characterized by a sharp increase in both the index of microcirculation and blood flow velocity, while postocclusive dynamics of change in these two parameters has the same character.

The results showed that the combined use of the LDF and the VCS methods could improve the accuracy of data interpretation. It allows comparing the change in the perfusion in certain tissue volume with local tissue blood flow velocity and direction in a single capillary.