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THE INFLUENCE OF LOCAL PRESSURE ON EVALUATION PARAMETERS OF SKIN BLOOD PERFUSION AND FLUORESCENCE

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ABSTRACT

It is well known that the pressure applied on optical diagnostic probes is a significant factor affecting the results of measurements. One of the main causes of such effect is the influence of the pressure on local blood flow. Taking into account holding pressure is necessary when developing new wearable electronics. Therefore, investigating the influence of local pressure on measurement results of wearable devices for optical diagnostic technologies is a relevant issue at present.

Pressure is a well-known technique for controlling optical properties of biological tissue. It increases diagnostic depth and volume as well as allowing evaluation of actual values of optical parameters of biological tissue in vivo (parameters of absorption, scattering, polarization, fluorescence, etc.) by reducing the influence of blood absorption.

The research aim of this work is the experimental study of the influence of local pressure on the skin - by optical probe - on measurement results from Doppler flowmetry (LDF) and fluorescence spectroscopy (FS).

Experiments were conducted using the optical non-invasive diagnostic device “LAKK-M” (SPE “LAZMA” Ltd, Russia). This device has embedded LDF (1064 nm) and fluorescence spectroscopy (excitation at wavelengths 365, 450, 532 and 637 nm) diagnostic channels. Furthermore, a custom developed detachable device for recording Doppler broadening spectra of probing laser radiation was used. The evaluation of Doppler spectra was performed by analyzing photocurrents of LDF-channel photodiodes. In order to assess skin blood volume fraction before and after pressure, diffuse reflectance spectra were registered by measurement setup containing halogen light source HL-2000-HP-232R, optic fiber probe R400-7 and “FLAME” spectrometer (“OceanOptics”, USA). To change the pressure value fixed on the optical probe, special tooling has been developed and manufactured using a 3D-printer.

During each experiment, pressure was changed stepwise from 0 to 40 kPa and then was reduced

back to 0 kPa. Palmar surface of fingers and distal end of the forearm were selected as areas of interest due to frequent use of these areas for optical non-invasive measurements, including in wearable electronics.

A total of 7 healthy volunteers aged 24±7 years were engaged in the research. At the first stage, influence of pressure on averaged LDF-signal level was investigated, alongside characteristics of Doppler spectra. Data were used to generate an averaged curve of blood perfusion reduction and to represent it in exponential approximation. The processing of Doppler spectra allowed the identification of the effect of velocity re-distribution of moving RBC in diagnostic volume when the pressure was changed. In addition, the moments of crossclamping of venule and arterial blood flows were captured. On average, procedure using maximum applied pressure led to a fall in perfusion level by 85 % from the initial level. Even at pressures of 5 kPa the perfusion level decreased by 25 %.

At the second stage, the influence of pressure on registered intensity of skin fluorescence was investigated. Before the main experiment, in order to assess saturation and blood volume fraction, diffuse reflectance spectrum was recorded from skin surface measurement area as well as background fluorescence at four excitation wavelengths. Subsequently, fluorescence spectra measurements were performed with stepwise increasing and decreasing pressure on optical probe. Finally, diffuse reflectance spectrum was registered again.

Data generated were used to obtain averaged curves of increasing fluorescence intensity with increasing probe pressure. At pressure 40 kPa fluorescence intensity increased at excitation wavelengths λ=365 nm by 95 %, λ= 450 nm by 105 % and λ=532 nm by 40 %. Moreover, fluorescence intensity increase at 5 kPa reached 30 % at λ=365 nm, 25 % at λ= 450 nm, 22 % at λ=532 nm. At excitation wavelength λ=637 nm, no significant influence of pressure on fluorescence intensity was revealed. Registered increase of fluorescence intensity at aforementioned wavelengths can be explained by decreasing blood content in sampling volume due to pressure increase. Mathematical modelling based on modified-Beer-Lambert law technique was used to model compensation of blood influence on fluorescence spectrum. Parameters of blood volume fraction for this model were assessed by diffuse reflectance spectra recorded during experiments. The result of modeling was compared with measurement results at the maximum pressure. It is hypothesised that influence of blood absorption is minimum when maximum pressure applied. The results of numerical compensation and experimental measurements acceptably match each other.

Thus, pressure on optical probe has sufficient impact on skin microcirculation to affect registered fluorescence intensity. Data generated in this study are of interest for design and development of diagnostic technologies for wearable devices. This data will also inform further investigation into issues of compensation of blood absorption influence on fluorescence spectrum, allowing increased accuracy and reproducibility of measurements by fluorescence spectroscopy methods in optical diagnosis.

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