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The influence of local pressure on evaluation parameters of skin blood perfusion and fluorescence

E.A. Zherebtsov[1,2], K.Y. Kandurova[1], E.S. Seryogina[1], I.O. Kozlov[1], V.V. Dremin[1], A.I. Zherebtsova[1], A.V. Dunaev[1], I. Meglinski[2]

[1] Orel State University named after I.S. Turgenev, Scientific-Educational Centre of "Biomedical Engineering", Biomedical Photonics Instrumentation Group, Komsomolskaya b. 95, Orel, Russia, 302026
[2] University of Oulu, Faculty of Information Technology and Electrical Engineering, Opto-Electronics and Measurement Techniques, Erkki Koiso-Kanttilankatu 3, Oulu, Finland, 90570

Introduction

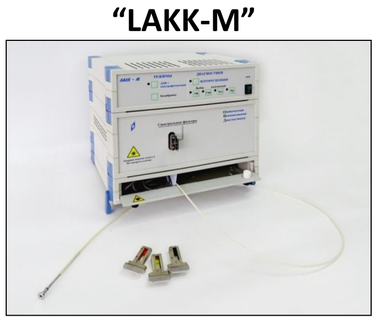
It is well known that the pressure applied on optical diagnostic probes is a significant factor affecting the results of measurements. One of the main causes of such effect is the influence of the pressure on local blood flow. Taking into account holding pressure is necessary when developing new wearable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

The aim of research

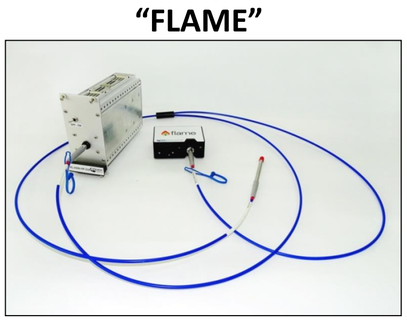
The research aim of this work is the experimental study of the influence of local pressure on the skin - by optical probe - on measurement results from Doppler flowmetry (LDF) and fluorescence spectroscopy (FS).

Experimental method and equipment

Fluorescence spectroscopy and Laser Doppler flowmetry "LAKK-M"



Diffuse reflectance spectroscopy HL-2000-HP-232R "FLAME"



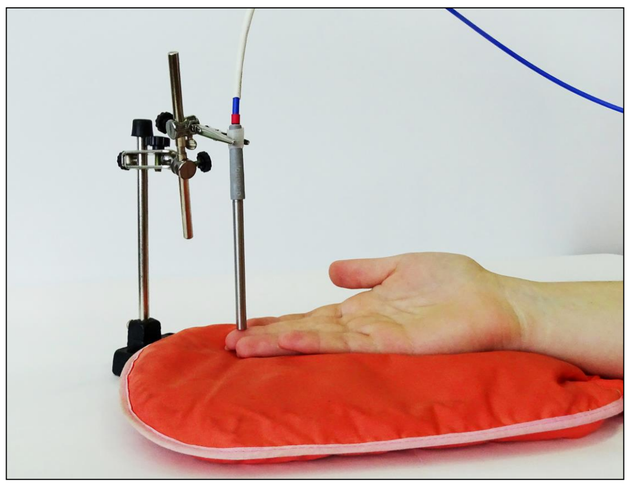
Special tooling designed and 3D printed

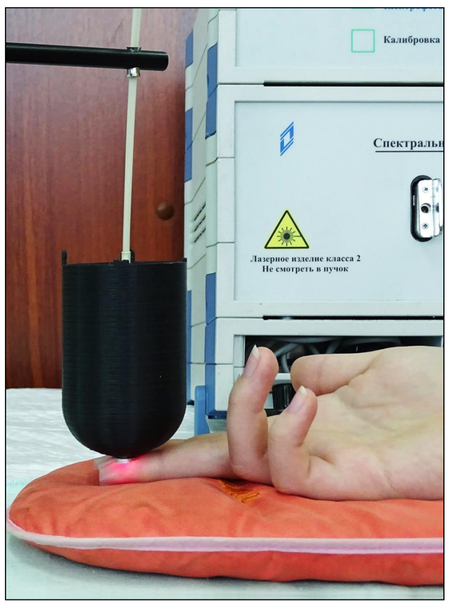
Experiments were conducted using the optical non-invasive diagnostic device "LAKK-M" (SPE "LAZMA" Ltd, Russia). This device has embedded LDF (1064 nm) and fluorescence spectroscopy (excitation at wavelengths 365, 450, 532 and 637 nm) diagnostic channels. Furthermore, a custom developed detachable device for recording Doppler broadening spectra of probing laser radiation was used.
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 special tooling has been developed and manufactured using a 3D-printer.

The Concept

Experimental study

A total of 7 healthy volunteers aged 24±7 years were engaged in the research.
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.

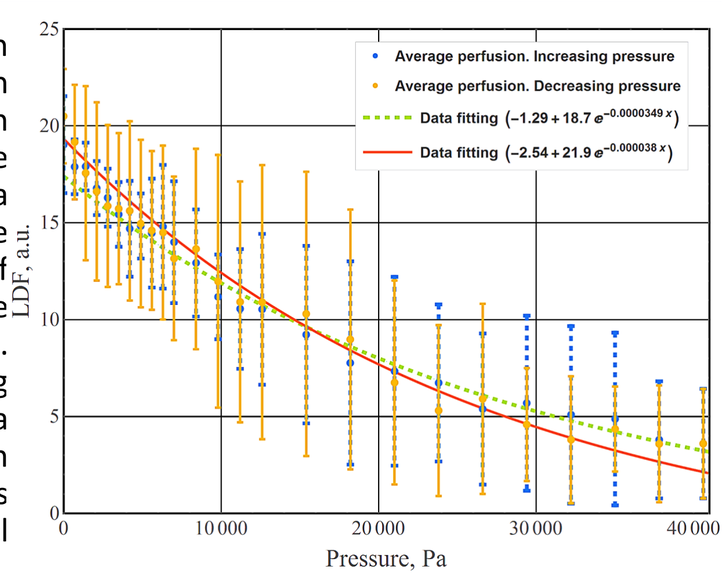


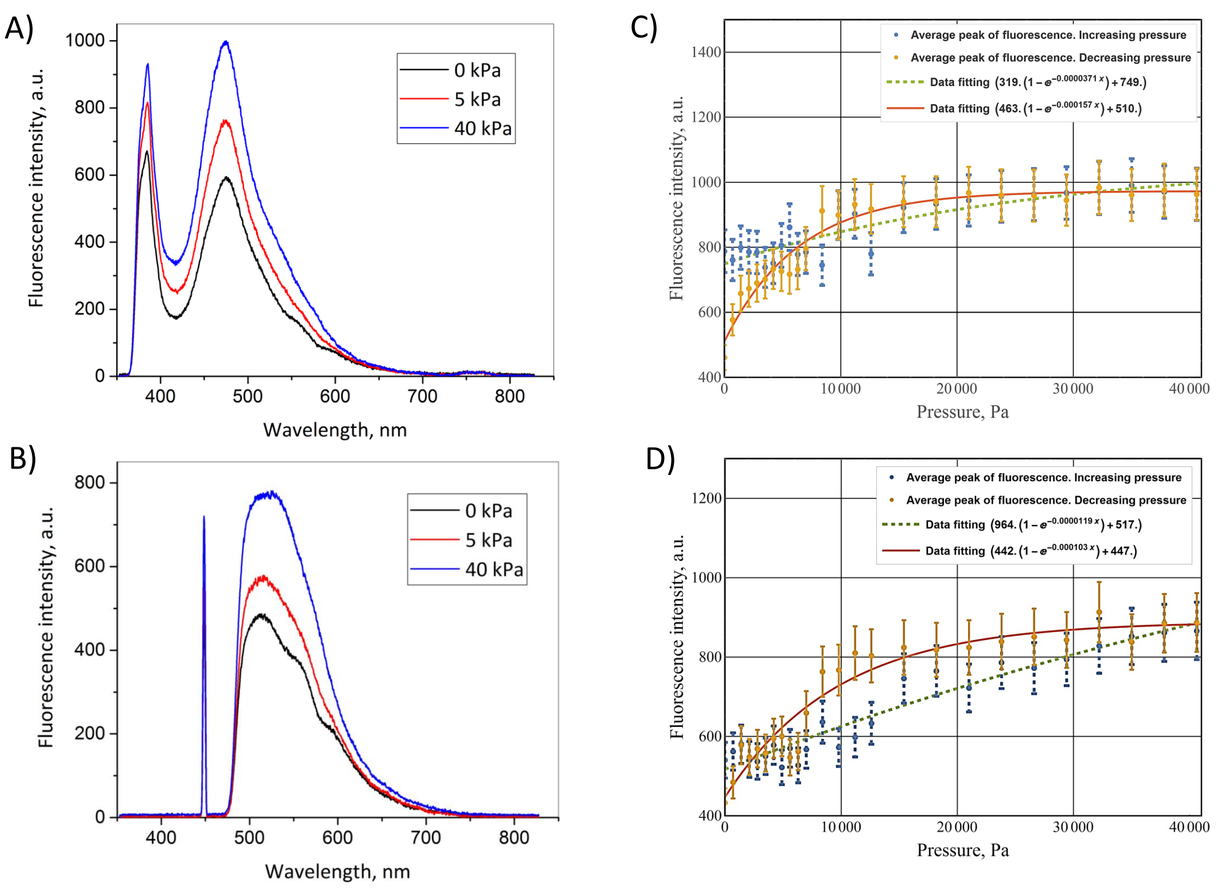


At the first stage, influence of pressure on averaged LDF-signal level was investigated, alongside characteristics of Doppler spectra.
At the second stage, the influence of pressure on registered intensity of skin fluorescence was investigated. Before the main experiment, in order to assess saturation 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.

Results and Discussion

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. 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 %.





Typical fluorescence spectra at pressures 0 kPa, 5 kPa and 40 kPa (A, B) and average peaks of fluorescence intensity for all volunteers (C, D) for wavelengths 365 nm 450 nm respectively

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.

Conclusion

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.

Acknowledgements

This work was supported by grant of the President of the Russian Federation for state support of young Russian scientists № MK-7168.2016.8.