Evaluation of blood microcirculation parameters by combined use of laser Doppler flowmetry and video capillaroscopy methods

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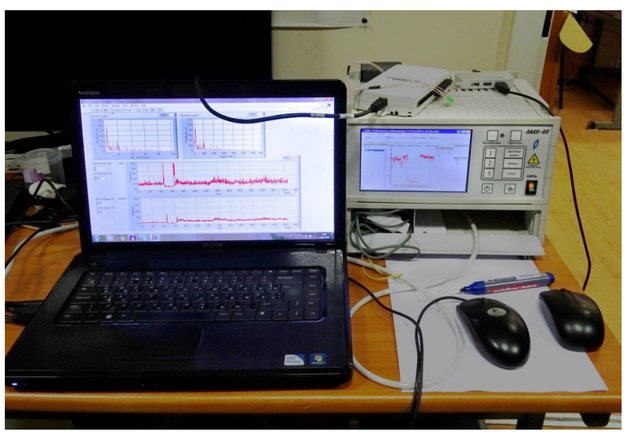
Introduction

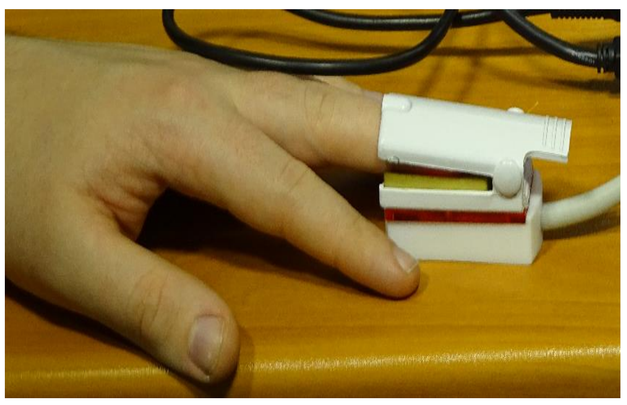
Non-invasive laser Doppler flowmetry (LDF) and video capillaroscopy (VCS) are widely used methods to study blood microcirculation parameters for early diagnosis of various diseases and to monitor the effectiveness of therapeutic measures. We present the results of simultaneous investigations of changes in tissue perfusion of the distal phalanx of the human fingers by LDF as well as changes in capillary blood flow velocity in the nail bed evaluated by the VCS method during arterial occlusion test.

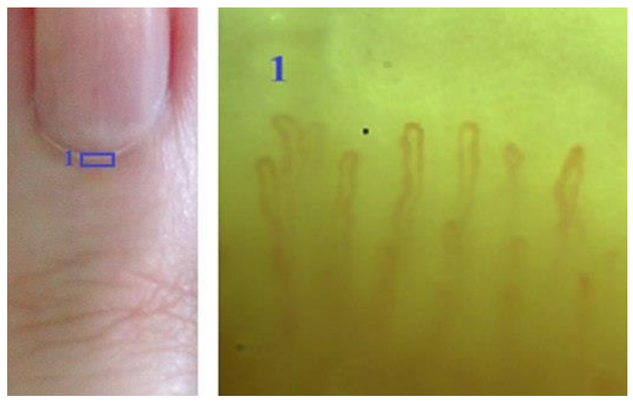
Experimental setup

Laser Doppler flowmetry setup based on "LAKK-OP" device and custom electronic board



Video capillaroscopy setup





LDF-probe, placed on middle finger of left hand

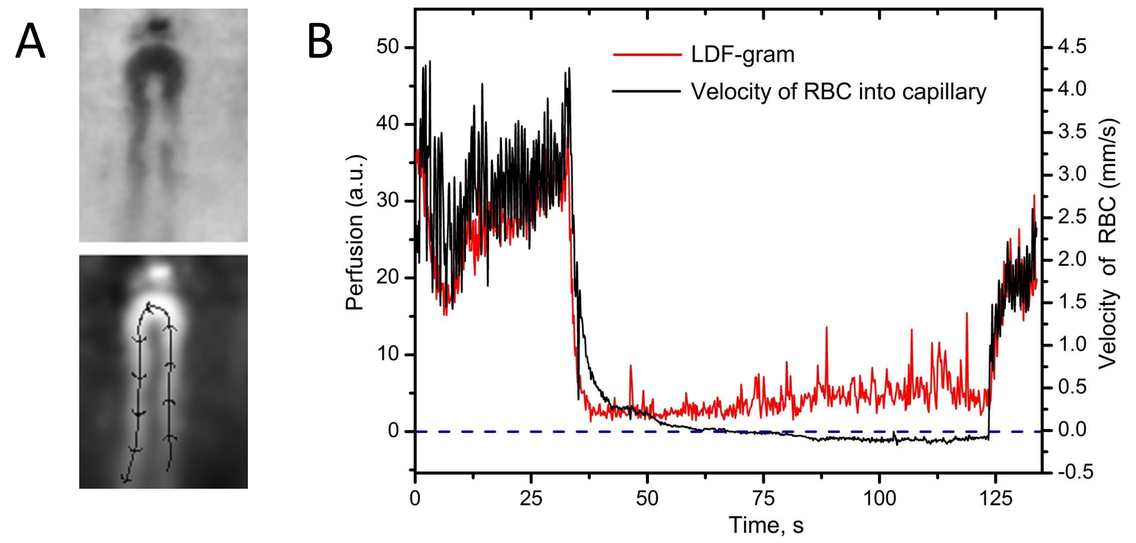
1 – Area of interest on nailfold of ring finger of left hand

Single mode 1064 nm laser was selected as the source of radiation for registration of blood perfusion. Optical fibers were used to deliver radiation to the skin and to collect backscattering light. Silicon photodiodes were used to convert detected radiation into photocurrent. In the next step, the signal is amplified in a custom electronic board. Analog-to-digital conversion was performed by data acquisition board NI USB 6211. Finally, NI LabVIEW environment installed on PC was implemented for signal processing. Registration of capillary blood flow was carried out utilizing an experimental set-up of capillaroscopy, consisting 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.

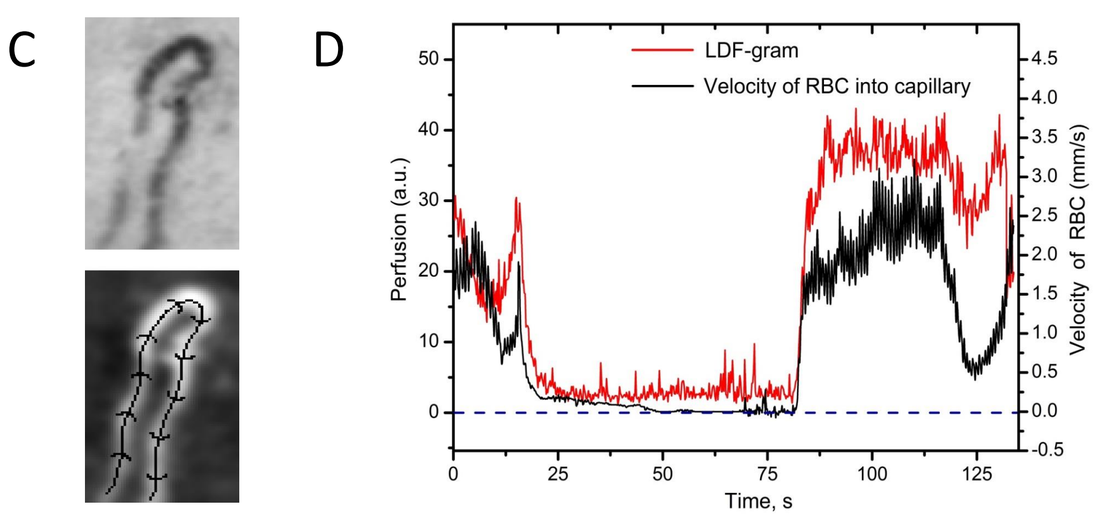
Experimental study

Experiments included the following procedures: recording of the background level of perfusion (0.25-0.5 min), occlusion test (1-1.5 min), post-occlusion recording (0.1-0.5 min). Occlusion pressure equalled 220 mmHg. Distal phalanx of middle finger of left hand was chosen as area of interest for laser Doppler flowmetry. The nailfold of ring finger was chosen for collecting of video capillaroscopy data. Index of microcirculation and video capillaroscopy data were obtained simultaneously. Sequences of received capillaroscopy video frames were processed with special algorithm. This algorithm performs stabilization and compensation procedures for frame drift correction. At the next stage, highlighted capillary is segmented and automation system creates capillary central line (Fig. A, C). Velocity of RBC into capillary is computed along this central line.

Results and Discussion



The features of some LDF-grams related to the detected records by VCS method have shown reverse blood flow. This effect points out (Fig. A) that occlusion leads to simultaneous reduction of blood flow in a single capillary from approximately 4 mm/s to small negative values and index of microcirculation in the distal phalanx of the finger from 30 to 2 perfusion units. Subsequent gradual increase in the index of microcirculation to 5 perfusion unit with continued occlusion is caused by detectable reverse blood flow in the capillaries. The absolute speed in capillaries increases gradually from 0 to 0.2 mm/s during the time of registration of the effect (40 s). End of the occlusion is characterized by a sharp increase in both the index of microcirculation and blood flow velocity.



A, C – Frames with capillaries
B, D – Graphs with RBC velocities into capillary and LDF-grams

The curves possess high degree of concordance during the local variations of blood perfusion before and after occlusion. However, this correlation is absent at occlusion period. LDF-grams have significant means and amplitude values despite the fact that blood flow in capillaries is near zero. It can be explained by weak influence of central regulation of blood circulation during occlusion.

Conclusion

The present results show that the combined use of the LDF and the VCS methods could improve the accuracy of data interpretation. It allows comparison of the changes in the perfusion in certain tissue volume with local tissue blood flow velocity and direction in a single capillary. As a result, this study substantiates the approach of empirical confirmation of the relationship between blood flow speed into capillaries and blood perfusion by LDF method.

Acknowledgements

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