The study of nail bed microcirculation by speckle-imaging technique

Dmitry N. Agafonov[1], Polina A. Timoshina[1], Maxim A. Vilensky[1], Valery V. Tuchin[1,2]
[1]Saratov State University, [2]Institute of Precise Mechanics and Control RAS

SEVENTH FRAMEWORK PROGRAMME

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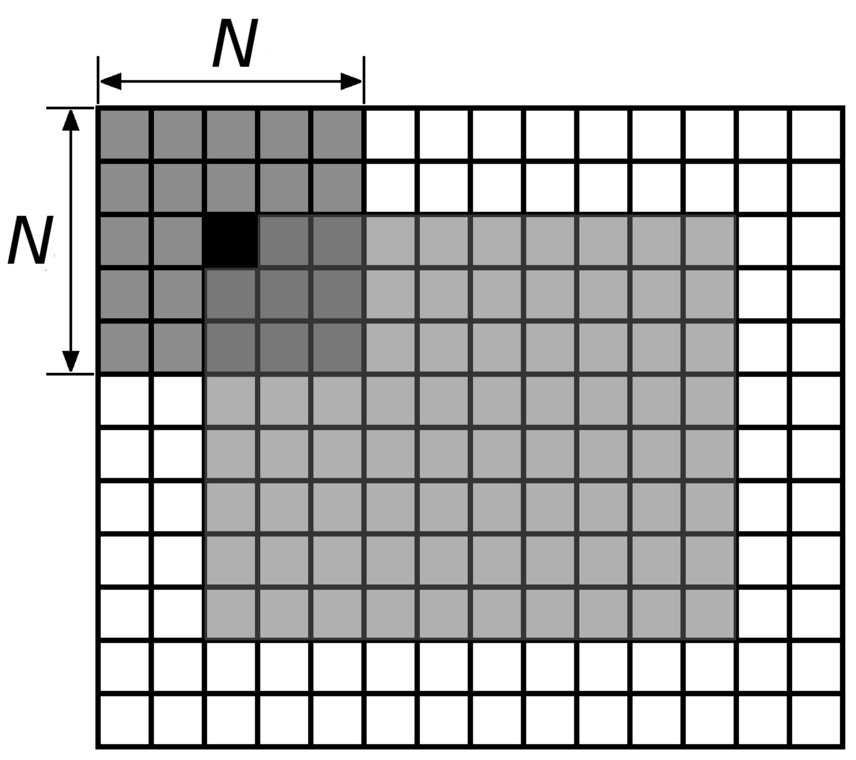
Abstract

Monitoring of the microcirculation dynamics is one of the possible diagnostic tools for various cardiac diseases and accompanying structural changes. Detecting micro-vascular and hemodynamic pathology can help in making proper medical decisions at diagnostic and treatment stages.

The results of experimental study of nail bed monitoring of microcirculation using spatial laser speckle contrast analysis technique (sLASCA) are presented.

Materials and Methods

In sLASCA square window with size of $N = 5$ or 7 pixels are typically applied to calculate speckle contrast values for recorded intensity distributions I_j over the region of interest:



$$K = \frac{\sqrt{\frac{1}{N^2-1}\sum_{i=1}^{N^2}\left(I_i - \frac{1}{N^2}\sum_{j=1}^{N^2} I_j\right)^2}}{\frac{1}{N^2}\sum_{j=1}^{N^2} I_j}$$

Custom software program written in LabVIEW (Version 8.5, National Instruments, Austin, Texas) was used and developed to acquire and process speckle images from monochrome CMOS camera (Basler A602F) in real time.

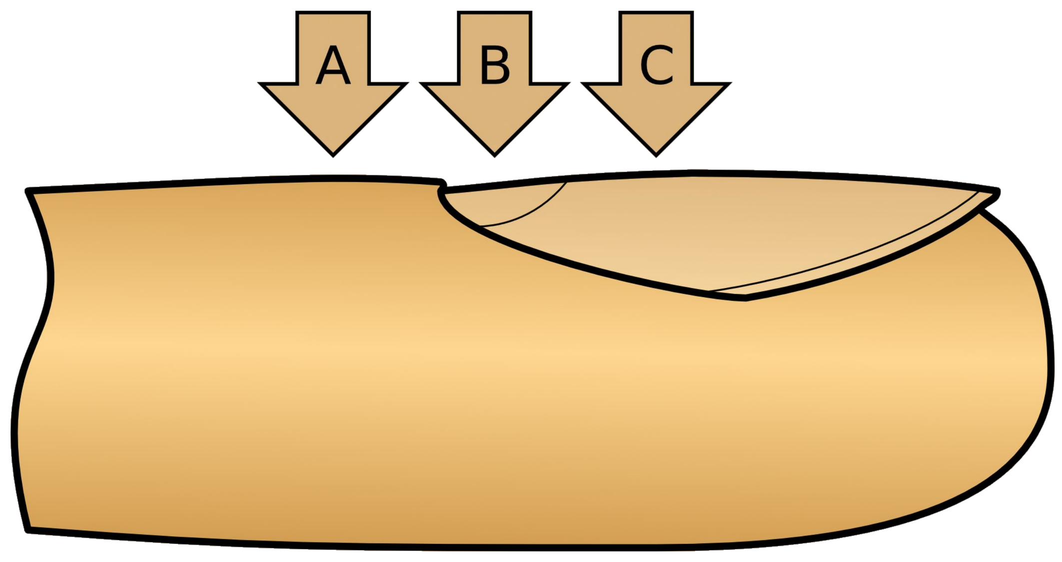
Resulting image of spatial contrast distribution was prepared by mapping calculated values K to inverse "intensity" values of 8 bit image hence producing "relative speed map" images.

Microcirculation dynamics in finger nail bed was investigated by controlled blood flow blockade using sphygmomanometer (model Medica CS-105) with subsequent fast cuff pressure release.

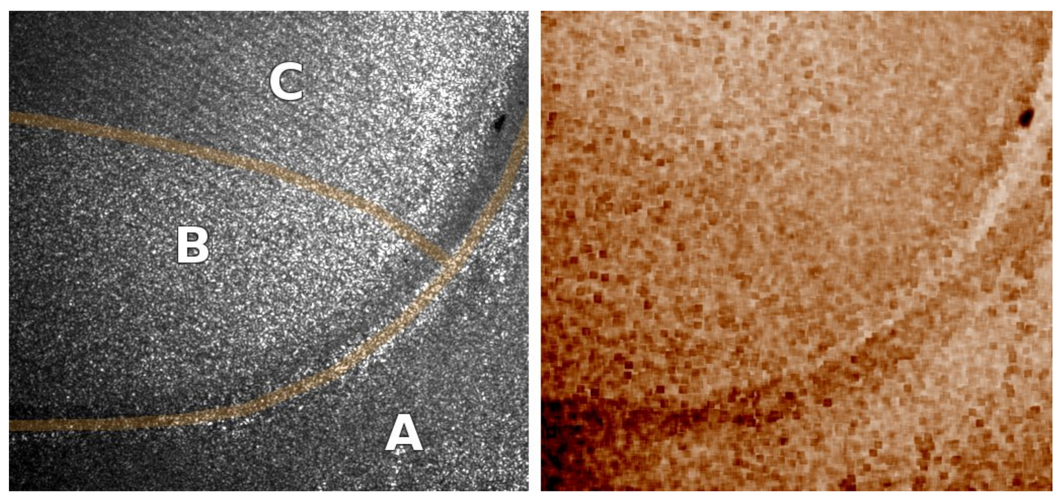
Experimental data was collected and processed at 25 iterations per second with averaging over 10x10 pixel region of nail fold (zone of interest A) for 5 volunteers.

Additional optical clearing agent (50% water solution of glycerol with dimethylsulfoxide (dmso)) was also used to increase method sensitivity by eliminating high scattering in epidermis.

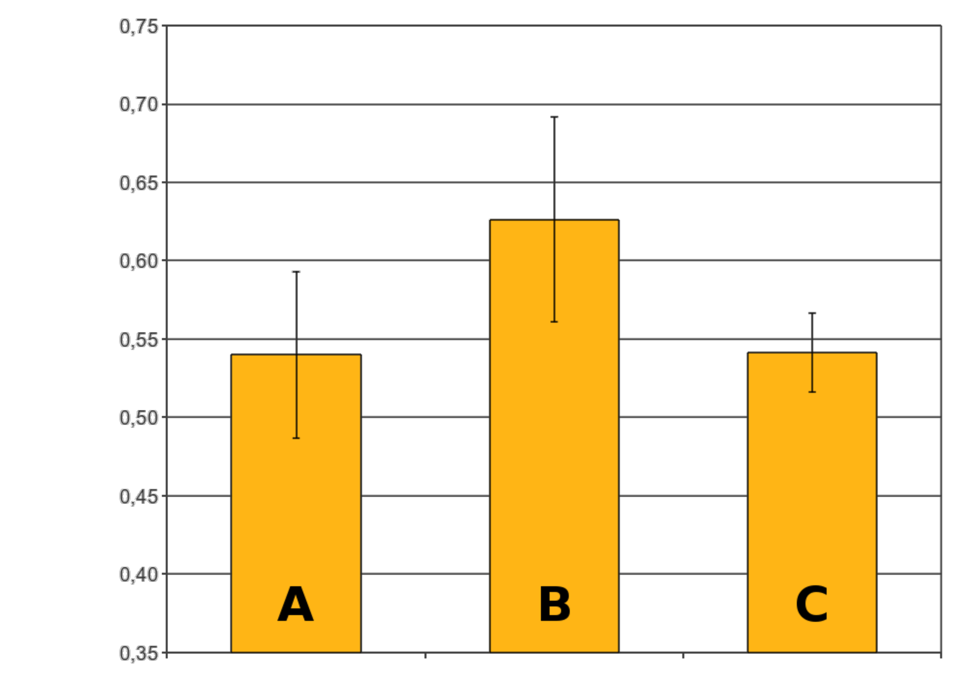
Microscopic observations of micro-vessels in cleared nail bed tissue was made to control structural changes during the course of blood blockade and subsequent release.



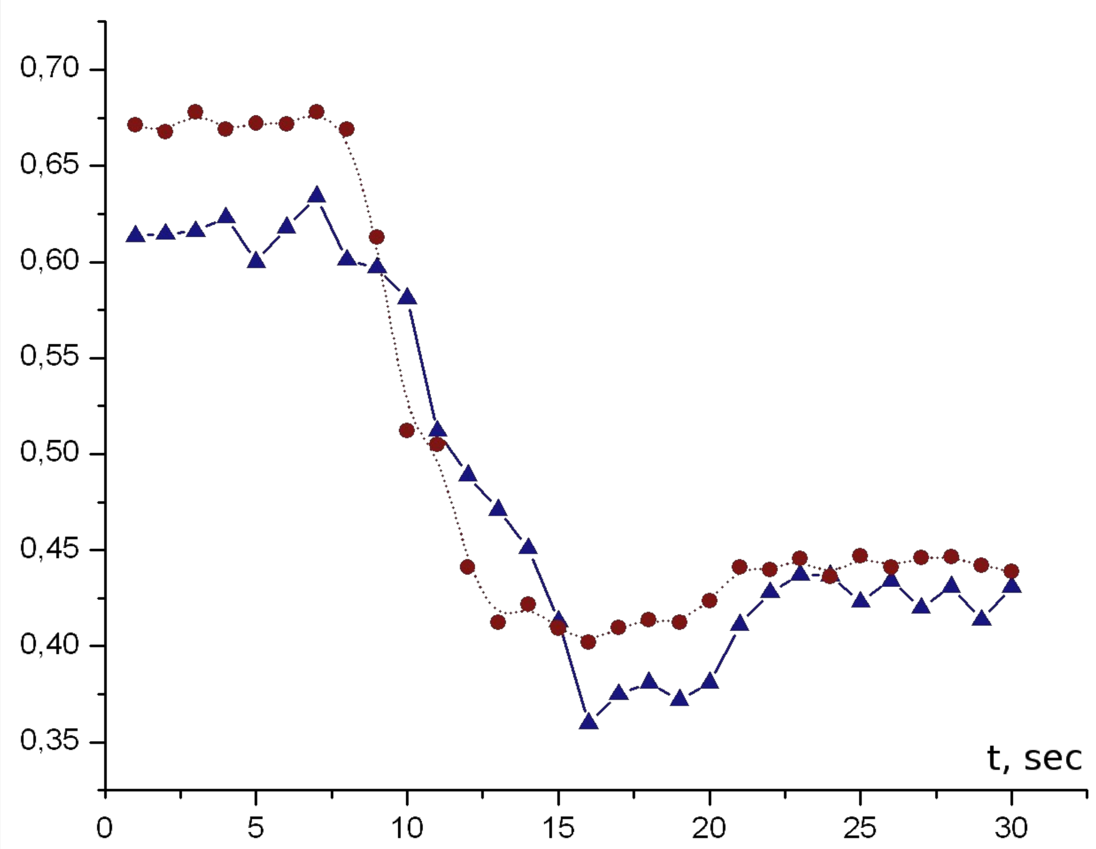
Finger nail bed zones of interest: A — nail fold; B — lunula; C — middle-nail.



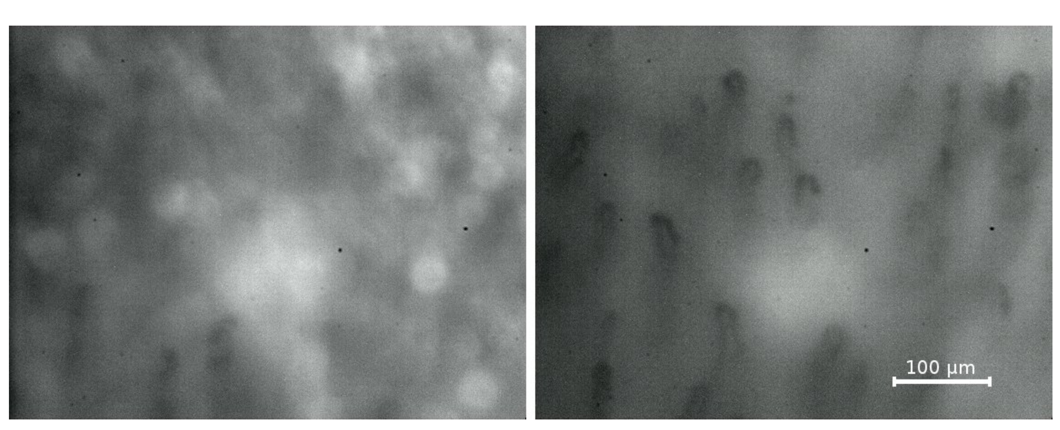
a) b)
Finger nail bed speckle contrast imaging (5x5 window): a) intensity image registered by digital camera; b) spatial contrast distribution calculated (inverted: lighter is lower contrast).



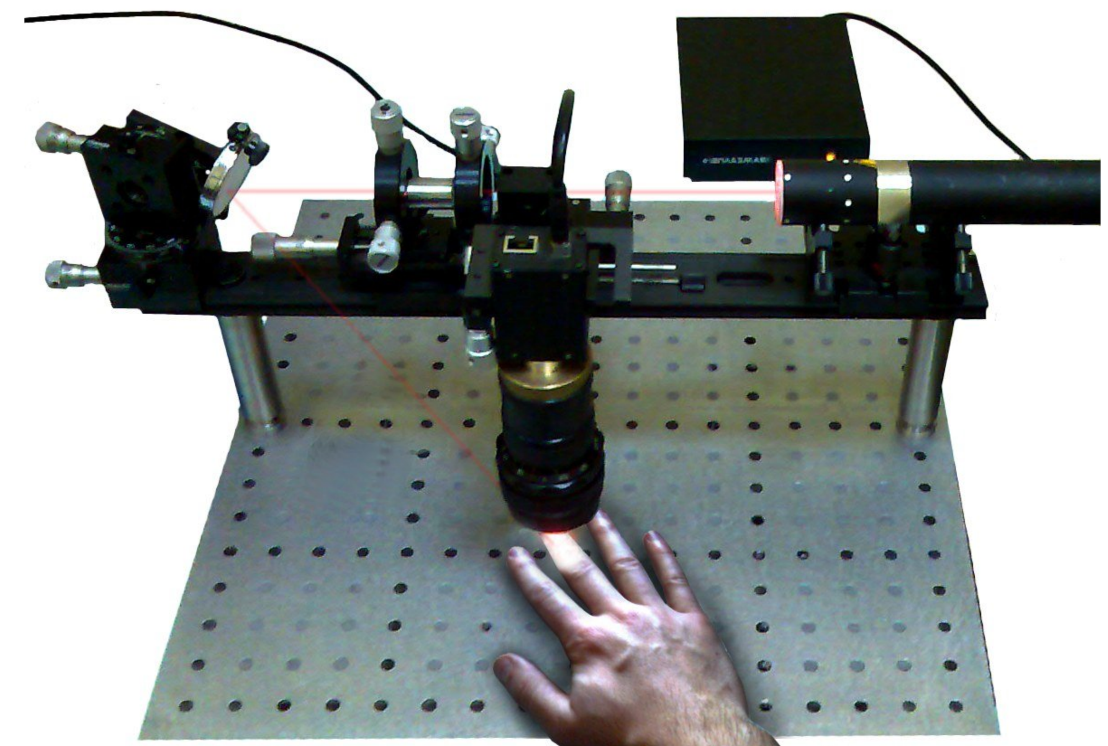
Contrast values averaged by zone of interest.



Contrast averaged over the zone A during course of blockade: blue triangles – dry skin; red circles – clearing agent applied. Sphygmomanometer cuff pressure was released at 8th second.



a) b)
Microscopic images of nail fold made with x10 magnification a) without and b) with clearing agent.



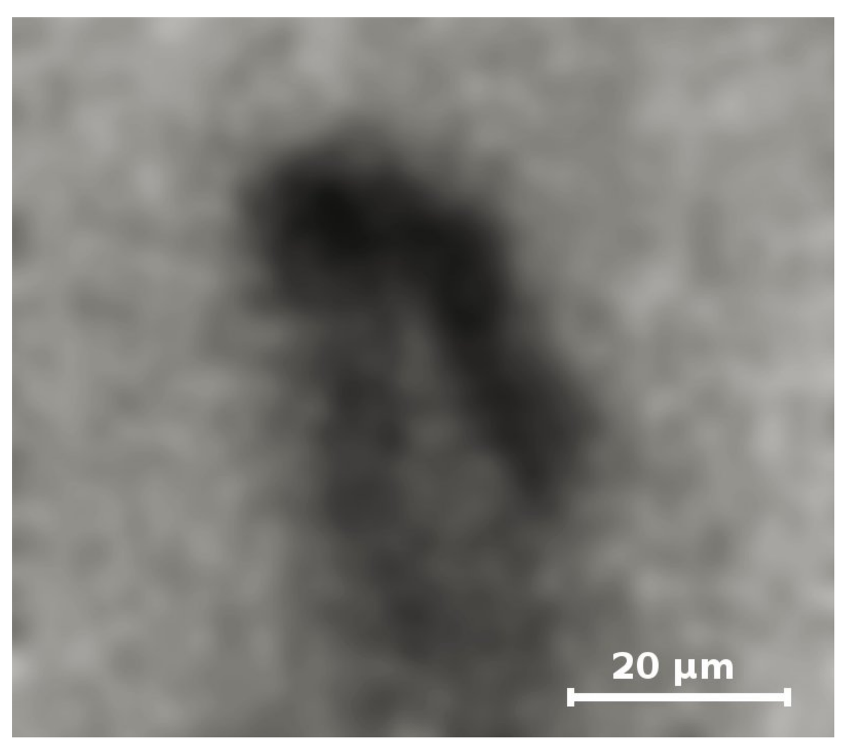
Experimental setup: nail bed was illuminated by He-Ne laser (λ=633 nm) via beam expander and collimating mirror and resulting speckle images were captured via CMOS camera by PC.

Results

Custom software and apparatus for real time LASCA studies (including microscopic) is developed, allowing for automatic digital camera set up and recording of captured video data and calculated values up to 100 fps. Sample sLASCA image of human finger nail is presented, showing differences in baseline contrast (and therefore blood flow) in nail bed zones.

Contrast analysis is shown to be sensitive for microcirculation changes in nail bed. It is found that contrast increases up to 0.60 and 0.68 (dry and optically cleared skin respectively) during blood blockade with sphygmomanometer cuff and falls to values below normal (0.37 and 0.42) within 6-8 seconds after pressure release, then slightly increases to baseline (0.43 and 0.44) within 10 seconds.

Microscopic observations disclosed the increase of mean diameter of vessel in capillary loop from 9 to 13 µm while blood flow blockade which demonstrate the obstruction of venous blood flow.



Microscopic image of single capillary loop in nail fold in normal state made with x10 objective lenses.

Acknowledgments

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