Laser diagnostics method for evaluation of properties of blood flow oscillations in rheumatologic patients

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Introduction

Microvascular system plays an important role in the transport of nutriment, hormone, oxygen, and the discharging of metabolic waste. This part of cardiovascular system is involved in the process of thermoregulation, and it possesses its own autoregulatory mechanisms.

The studying of properties of blood flow oscillations in rheumatologic diseases is important in assessing of the blood vessels functional state and the degree of their involvement into the pathological process in the background of the existing system disorganization of connective tissue.

Method

Experimental study

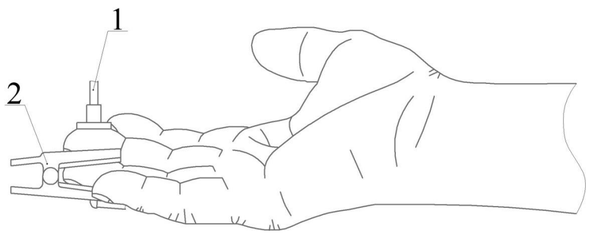
- 32 healthy volunteers (HV).
- 60 patients with rheumatic diseases (PRD).

Experimental equipment

Experimental systems “LAKK-OP” and “LAKK-M” (SPE “LAZMA” Ltd., Russia)

Diagnostics method

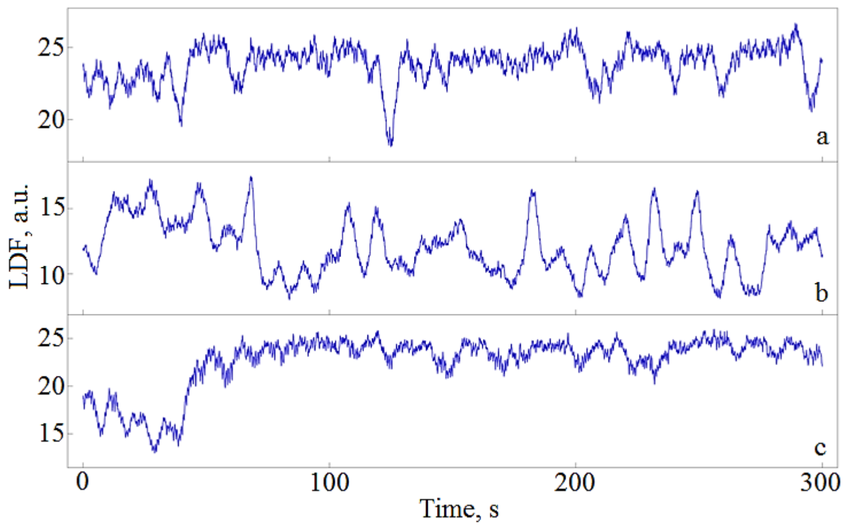
Laser Doppler flowmetry (LDF) + Functional test – Cold Pressor Test (CPT)



Schematic presentation of the LDF probe positioning on the finger:
1 – LDF probe, 2 – pulseoximetry sensor

Study protocol

Stage	Basic test 1	CPT T_w=15 °C	Basic test 2	Rest period	Basic test 3
Stage duration, min	5	5	5	15	5
Study duration, min	35				



Example of the measured LDF signals for HV, obtained at normal conditions (a), immediately after cold exposure (b), and 20 min after finishing CPT (c)

Algorithm for LDF-signals processing

The obtained LDF signals were decomposed by using a wavelet transform:

$$W_x(\nu,\tau)=\nu\int_{-\infty}^{\infty} f(t)\psi^*(\nu(t-\tau))dt, \quad (1)$$

where $*$ means complex conjugation. The Morlet wavelet written in the form:

$$\psi(t)=e^{2\pi i t}e^{-t^2/\sigma}, \quad (2)$$

was used with the decay parameter σ = 1. Integrating the power over time gives the global wavelet spectrum

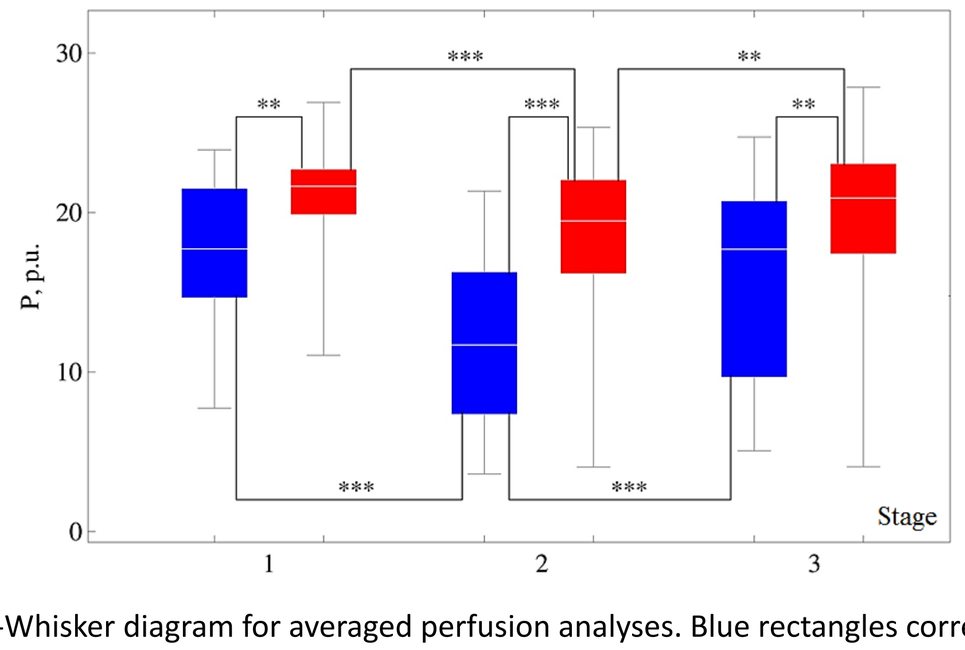
$$M(\nu)=\frac{1}{T}\nu\int_0^T |W(\nu,t)|^2 dt. \quad (3)$$

The wavelet coefficients were counted for the frequency band 0.01–2 Hz with the logarithmic partitioning on 50 frequencies subbands.

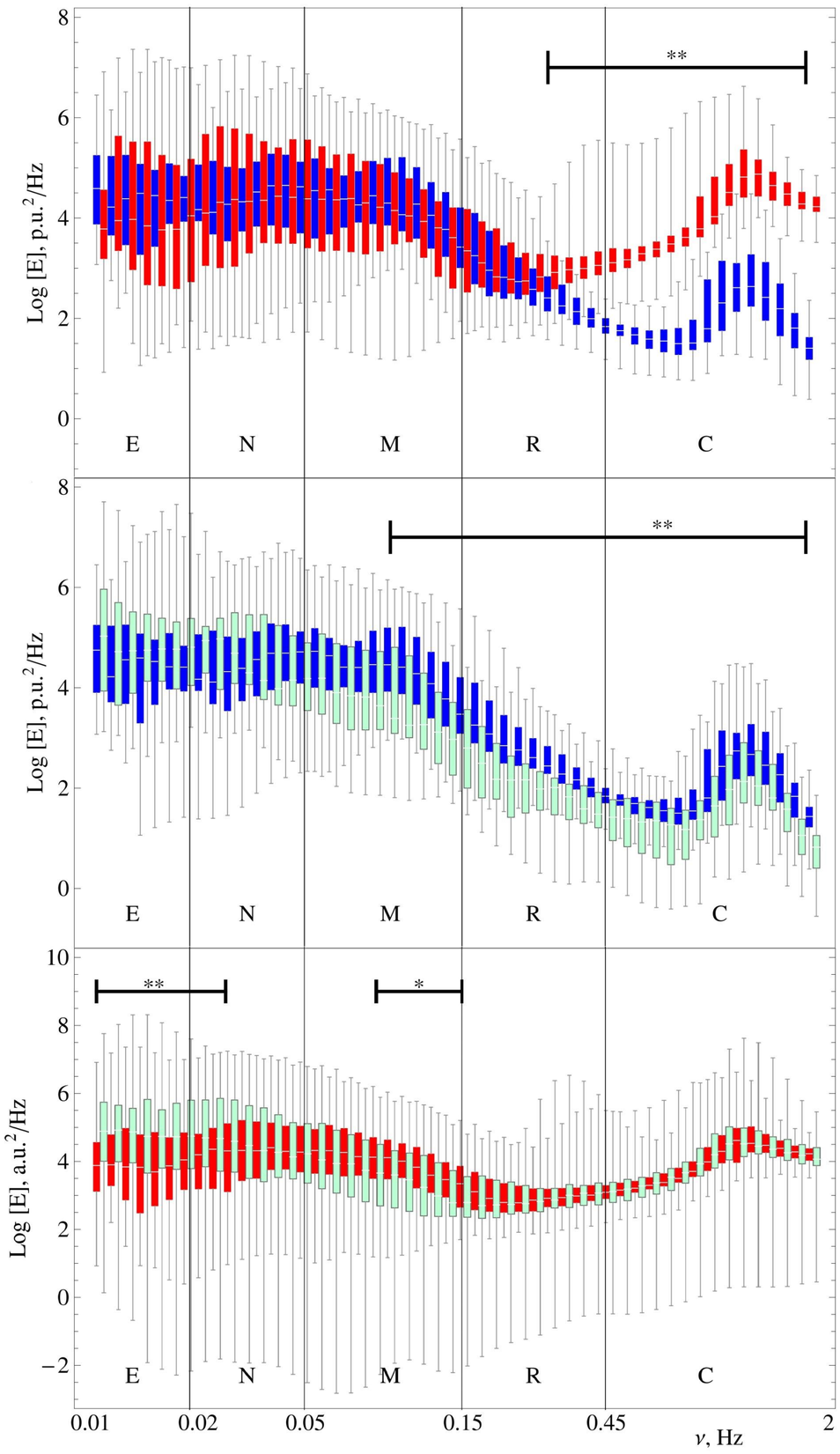
Discussion

- PRD had higher perfusion in basal conditions and after cooling and weaker response on the cold stimulation then HV. This reaction of peripheral vascular system of PRD on the cooling indicates a violation of the processes of thermoregulation.
- In PRD higher amplitudes of oscillation in high frequency range (cardiac and respiratory) can be associated with morphological abnormalities of microvascular structure of PRD.
- These abnormalities can be associated with decrease of damping properties mechanism: increasing the capillary diameter as it takes place in mega-capillaries, decrease a hydrodynamic resistance of the capillary per unit of volume of filtrated blood. The arterial stiffness increases. The thicker capillaries less energy is lost for the erythrocyte deformation.

Results



Box-Whisker diagram for averaged perfusion analyses. Blue rectangles corresponds to the group of HV, red ones to the group of PRD. Numbers indicate time intervals: (1) – before CPT, (2) – immediately after, and (3) – 20 min after the CPT. Stars indicate significance in the difference: $*$ – $p < 0.05$, $**$ – $p < 0.01$, $***$ – $p < 0.005$



Box whisker diagrams for the power spectral density: (top) for HV (blue) and PRD (red) at normal conditions; (middle) for HV only, taken at normal conditions (blue) and after the CPT (light green); (bottom) for PRD only, at normal conditions (red) and after CPT (blue) at normal conditions. Solid stretches in the upper part of the plot indicated frequency bands, where the difference between HV and PRD with pathology is significantly different. $*$ indicates $p < 0.05$ and $**$ – for $p < 0.01$

Conclusion

The using this diagnostic method and pulse wave amplitude can be useful clinical method for diagnostics and treatment monitoring of the microvascular abnormalities in rheumatic disease.

Acknowledgments

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