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Influence of the Body Position on Skin Blood Microcirculation Measured by Wearable Laser Doppler Sensors

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Abstract: In this talk we demonstrate what kind of relative alterations can be expected in average perfusion and blood flow oscillations during postural changes being measured in skin of wrists by wearable laser Doppler flowmetry (LDF) sensors.

1. Introduction

One of the most important systems of our body is the cardiovascular system. However, the diseases associated with it and their complications are the considered leading cause of death in the world. At the same time, there are currently no available methods for the early diagnosis of disorders of the cardiovascular system at the level of microcirculation implemented in clinical practice.

Earlier studies have shown a significant variability of the cardiovascular system parameters associated with the position of the volunteers' bodies. Such factors as gender and age are shown to significantly affect the reactivity of blood flow in response to postural changes [1]. It is also known that different anatomical parts of the human body demonstrate differences in the blood flow regulation mechanisms [2]. In that respect, regional variability of the studied effects in microcirculation should also be taken into account. Previous studies reported that the low-frequency mechanisms of microcirculation regulation (endothelial, neurogenic, and myogenic) measured with the laser Doppler flowmetry (LDF) technique differ between the arm and leg regions under thermoneutral conditions [3,4]. It has also been shown that regulation of microcirculation differs in the leg and forearm under local heating [4]. The regions of glabrous and nonglabrous skin are also reported to have different types of response in the parameters of blood perfusion under the functional tests [5].

The use of compact vertical-cavity surface-emitting laser with a wavelength of radiation in the near-infrared range makes possible to develop a wearable device that implements LDF method. These flowmeters are used to study changes of microcirculatory system at various points of the body [6,7], as well as to study age-related and pathological changes in the regulatory mechanisms of blood flow [8,9].

The purpose of this work was to study the reaction of the microcirculation to the changes in the body position using wearable laser LDF analyzers.

2. Material and methods

To assess the influence of body position on the microcirculation, two wearable laser Doppler flowmeters were used (SPE "LAZMA" Ltd (Moscow, Russia)). The LDF method is based on laser probing of the tissue and analysis of the light reflected from the red blood cells. The devices have identical laser Doppler flowmetry channels for measuring microcirculation blood flow. Each device also has a built-in accelerometer to compensate for motion artefacts during measurement and a skin temperature measurement channel. Data from the devices is transmitted via the Bluetooth channel, which makes it easy to use them during the functional tests. An example of recording the index of microcirculation is shown in Figure 1 (left panel). Also, Figure 1 (right panel) shows an example of the amplitude-frequency analysis of the received signal, which allows evaluating the mechanisms of regulation of the microcirculatory system. Mechanisms of regulation can be divided into active (endothelial activity, innervation of the study area, and the work of precapillary sphincters) and passive mechanisms (resulting from a respiration and a heartbeat) depending on the person's ability to consciously influence them.

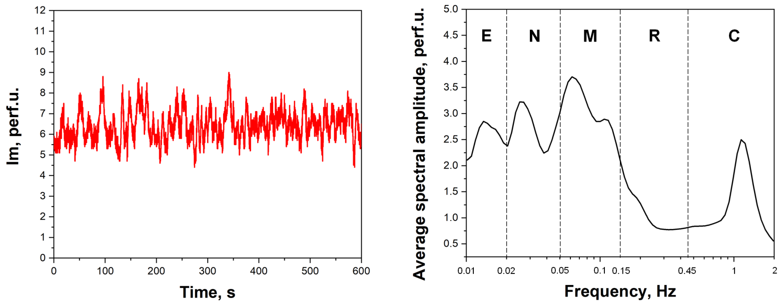

Fig. 1. Example of LDF recording (left panel) and amplitude-frequency analysis (right panel)

The group of 10 conditionally healthy male volunteers, whose average age was 44±12 years, participated in the study. The sensors were located at 2 points of the body: devices were fixed on the distal third of the right and left forearms. The studies were carried out on a turntable with a mechanical drive in the same order for all the volunteers: 1) supine position; 2) orthostasis (+75°); 3) head-down position (-15°, the Trendelenburg position). The index of microcirculation was measured for 10 minutes in each position of the body, and wavelet analysis was performed for each signal recorded.

3. Results and discussion

The obtained results are shown in Figure 2. When moving from the supine position to orthostasis (the measurement area is below the level of the heart), the level of skin perfusion has an unreliable downward trend, which is entailed by a significant decrease in the amplitude of pulse fluctuations in blood flow and the amplitude of vasomotion of all tone – forming mechanisms of microcirculation – endothelial, neurogenic and myogenic, which indicates an increase in their tone [10]. An increase in the tone of the precapillary arterioles leads to their narrowing and a decrease in the flow of arterial blood (the amplitude of pulse fluctuations) to the capillaries.

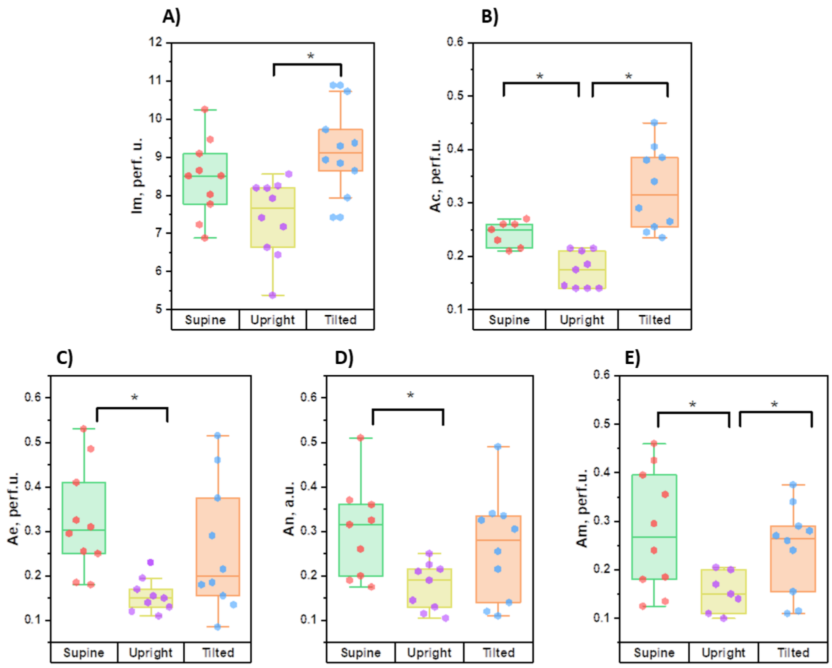

Fig. 2. Fig. 2. Analysis of the parameters of microcirculation in the wrists during different body position: a) average blood perfusion; b) cardiac oscillations; c) endothelial oscillations; d) neurogenic oscillations; e) myogenic oscillations (∗- The statistically significant difference between the values was confirmed with $p < 0.05$ using Mann-Whitney test)

When changing the position from orthostasis to the Trendelenburg position (the measurement area is above the heart level), the level of skin perfusion significantly increases and is entailed by a significant increase in the

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amplitude of pulse fluctuations of microcirculation (an increase in blood flow to the capillaries) and the amplitude of myogenic vasomotions (a decrease in the basal tone of smooth muscle cells of microvessels) with an unreliable tendency to increase the amplitude of endothelial and neurogenic vasomotions.

The amplitude of endothelial oscillations during the transition of volunteers from a supine to an upright position is observed to decrease significantly, which may indicate a decrease in the activity of metabolic processes occurring in the wrist area.

4. Conclusions

In this study, changes in the average microcirculation index and regulatory processes were evaluated when the volunteer's body position changed. The position of the body is one of the factors influencing the work of the microcirculatory bed and metabolic processes. The results obtained will be useful in the development of protocols for studying the features of the microcirculatory blood flow including daily monitoring of microcirculation. The results also facilitate to the possibility of integrating the LDF channel into wearable gadgets for assessing the state of human health and early diagnosis of disorders of the cardiovascular system.

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