Detection of masked hypertension based on laser Doppler flowmeter measurements

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ABSTRACT

The possibility of using the laser Doppler flowmetry (LDF) method for the diagnosis of masked hypertension is considered. Significant trends in changes in parameters between groups of volunteers were identified. This indicates the possibility of using the LDF method to make decisions about the further follow-up of patients for the presence of a hidden increase in BP.

Keywords: laser Doppler flowmetry, masked arterial hypertension, blood perfusion

1. INTRODUCTION

Masked arterial hypertension (MAH) is one of the phenotypes of arterial hypertension (AH) associated with target organ damage and the development of cardiovascular complications, which are one of the leading causes of disability and mortality in the Russian population. The disease is asymptomatic and characterized by an average level of BP at the doctor's office, which determines the difficulty of diagnosing MAH. Currently, the only methods for diagnosing MAH are home BP monitoring (HBPM) and ambulatory BP monitoring (ABPM). Thus, one of the most important tasks of health care is to reduce cardiovascular risk by developing and implementing in clinical practice affordable and straightforward methods for diagnosing hidden increases in BP during dispensary observation of the population.

Possible solution to the existing problem may be the use of a popular optical method for diagnostics of the state of the microvascular bed. Laser Doppler flowmetry (LDF) is the method.[1] LDF is based on the sensing of epithelial tissue of a living biological object (BO) by low-intensity laser radiation of a certain length wavelength (red or infrared wavelength), with the subsequent registration of the backscattered BO radiation and determination of dynamic parameters of microcirculation, such as the index of microcirculation (Im) and frequency rhythms of the microcirculation (Ai), from the Doppler frequency shift of laser radiation in the scattering of this radiation moving the formed elements of the blood (FEB). This frequency shift is contained in the recorded backscattered radiation from BO and depends on the speed of light-scattering FEB, mainly red blood cells.

The method also allows us to assess the state of local mechanisms of blood flow regulation, since the recorded signal is an overlap of several oscillatory processes. Estimation of the contribution of various oscillations to the overall signal level is possible using LDF signal processing by wavelet analysis. Currently, there are five main factors that have an impact in a certain frequency range. Endothelial vibrations (0.0095-0.021 Hz) are caused by the activity of cells of the inner layer of blood vessels, neurogenic (0.021-0.052 Hz) - are formed under the action of under the influence of nervous regulation of blood vessels, myogenic vibrations (0.052-0.145 Hz) are the result

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of vascular smooth muscle activity, respiratory (0.145-0.6 Hz) and cardiac (0.6-2 Hz) vibrations are generated due to the distribution of respiratory and pulse waves through the vessels.[2]

The widespread use of the LDF method for the diagnosis of arterial hypertension and latent hypertension is complicated by the high variability of the obtained indicators. This problem was considered by group from MONIKI (Moscow, Russia).[3] The following solutions were proposed to increase the sensitivity and specificity of the method: the use of functional test (heating test) in conducting the LDF study, as well as the transition to relative values from absolute values.

Increased blood perfusion in the skin in some patients with hypertension was dedicated. It is explained by a decrease in peripheral vascular tone, which is presumably a compensatory reaction of the body in response to increased blood pressure.[4] It was also found that patients with arterial hypertension are characterized by a decrease in vasomotor activity of microvessels with an increase in the tone of the resistive link of the microcirculatory bed against the background of activation of passive mechanisms of blood flow modulation.[5]

Many scientists are interested in changing the parameters of LDF in MAH. In particular, it was found that subjects with MAH revealed microcirculation is altered with elevated resting flowmotion of sympathetic and myogenic origin.[6]

The purpose of this work was to evaluate the possibility of using the laser Doppler flowmetry (LDF) method for the detection of masked hypertension.

2. MATERIALS AND METHODS

Study included 80 men aged 30 to 60 years (46 ± 8) who subjectively considered themselves healthy, did not make any complaints and did not take any medications regularly. All subjects underwent LDF blood perfusion measurements on the left forearm and ABPM after the physical examination. The participants were divided into three groups according to the recommendations of the European Society of Cardiology,[7] depending on the office BP and SBPM indicators. Group 1 included 29 men with normal BP (46 ± 8); group 2 included 27 men with MAH (45 ± 9); 24 men were in the 3rd group with a persistent increased BP (48 ± 11).

Table 1: Groups of volunteers and patients

	Healthy volunteers	MAH	Arterial hypertension
Number of volunteers	29	27	24
Age	46 ± 8 years	45 ± 9 years	48 ± 11 years

The measurements were conducted with the laser blood microcirculation analyzer LAKK (SPE "LAZMA", Moscow, Russia). This analyzer has two LDF registration channels with the semiconductor laser source at 800 nm. Perfusion registration was performed within 10 minutes. The Volunteers were in a lying position, hands were placed at the level of the heart.

3. RESULTS AND DISCUSSION

Index of microcirculatory (Im) did not differ significantly between the groups, but there is an unreliable trend to reduce skin perfusion in the MAH group relative to group 1 – 3.09 and 3.69 (p=0.078) (Fig.1).

When analyzing the amplitude of vasomotion of tone-forming mechanisms (Ai), which reflect the vasomotor activity of resistive arterioles, there is an unreliable trend towards increasing the amplitude of endothelial vasomotion in the MAH group in comparison with the normotonic group – 0.2 and 0.16 (p=0.093) (Fig.2).

Neurogenic amplitude vasomotions were significantly lower in the group with AH relative to MAH - 0.13 and 0.2 ($p < 0.05$).

The amplitudes of myogenic oscillations between the groups were not significantly different. Passive mechanisms (respiratory, pulse) also showed no significant differences. Significant increase in the contribution of endothelial oscillation is noted. When a vasomotor activity is normalized to the perfusion level (Ai/Im×100),

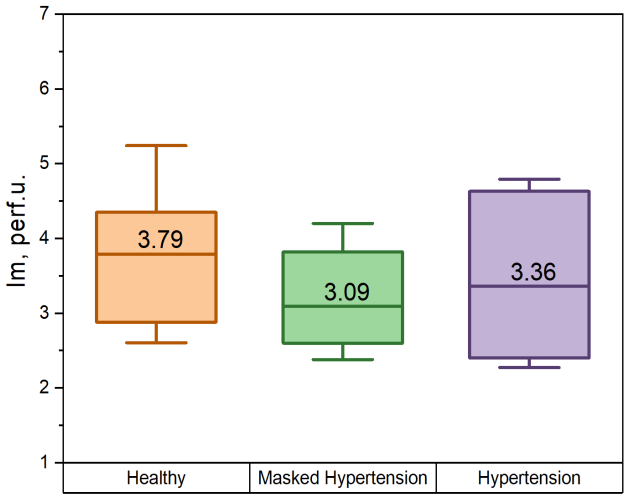

Figure 1: Index of microcirculation

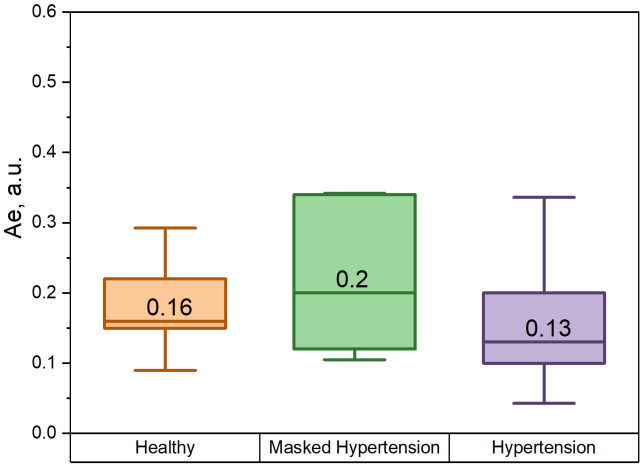

Figure 2: The amplitude of the endothelial oscillations

which reflects the contribution of the blood flow modulation mechanism to tissue perfusion, there is a significant increase in the contribution of the endothelial vasomotion mechanism to tissue perfusion (Ae/Im×100) in the MAH group relative to group 1 and 3 – 5.82, 4.32 and 3.7, respectively ($p < 0.05$) (Fig.3).

The contribution of pulse fluctuations (Ac/Im×100) to tissue perfusion is significantly higher in subjects of groups 2 and 3 relative to the control group – 8.89, 8.64, and 7.0 ($p < 0.05$) (Fig.4).

There were no significant differences in the perfusion contribution of the other mechanisms.

In patients with MAH, the increase in the amplitude of endothelial vasomotions is presumably compensatory, aimed at maintaining tissue homeostasis against the background of reduced tissue perfusion. An increase in the contribution of pulse fluctuations in both groups of hypertensive patients may be associated with an increase in the level of BP (the rate of propagation of the pulse wave).

4. CONCLUSIONS

Masked arterial hypertension is characterized by high blood pressure only during working hours or during psychoemotional disorders, which makes it much more difficult to diagnose. Therefore, the application of laser Doppler flowmetry can be a useful tool for making a decision about further follow-up examination for the presence of a hidden increase in blood pressure. This requires further comprehensive research.

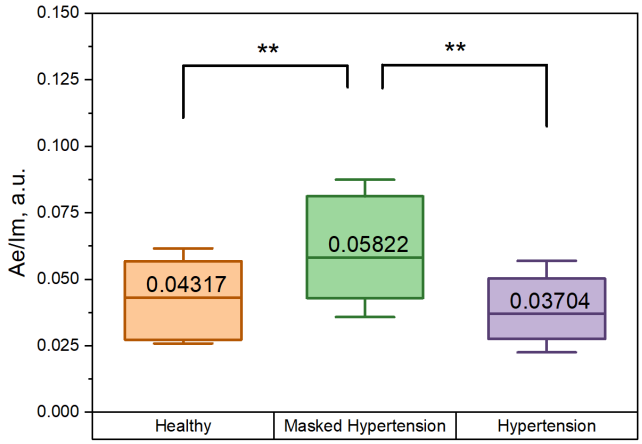

Figure 3: The amplitude of endotelial oscillation normalased at index of microcirculation

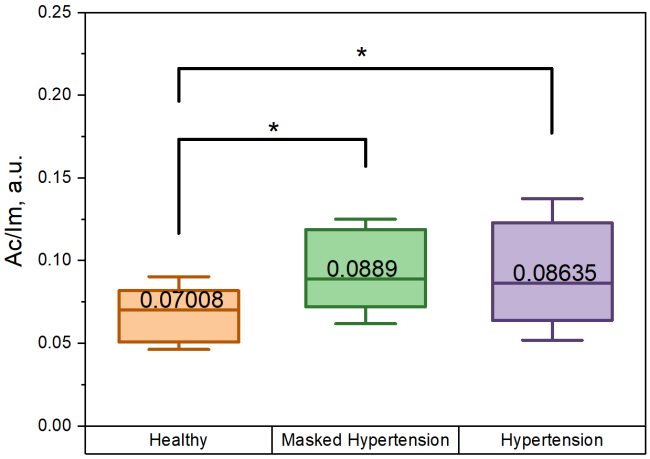

Figure 4: The amplitude of cardiac oscillation normalased at index of microcirculation

ACKNOWLEDGMENTS

This work were funded by the Russian Foundation for Basic Research (RFBR), the research project 20-08-01153A.

REFERENCES

[1] GRYGLEWSKA, B., NECKI, M., and CWYNAR, M. BARON, T. G. T., [*Functionaldiagnostics of the state of microcirculatory and tissue systems: fluctuations, information, non-linearity: hands-on for doctors*], LIBROKOM, M: (2010).

[2] Lancaster, G., Stefanovska, A., Pesce, M., Marco Vezzoni, G., Loggini, B., Pingitore, R., Ghiara, F., Barachini, P., Cervadoro, G., Romanelli, M., and Rossi, M., "Dynamic markers based on blood perfusion fluctuations for selecting skin melanocytic lesions for biopsy," *Scientific Reports* **5**, 12825 (2015).

[3] Glazkova, P., Terpigorev, S., Kulikov, D., Ivanov, N., and Glazkov, A., "Ways to increase the diagnostic significance of laser doppler flowmetry in assessing skin microcirculation in patients with arterial hypertension," *Arterial Hypertension* **25 (1)**, 74–83 (2019).

[4] Rogatkin, D., Glazkova, P., Kuliko, v. D., Glazkov, A., Terpigorev, S., Shekhyan, G., Kozlova, K., and Makmatov-Rys, M., "Dynamic markers based on blood perfusion fluctuations for selecting skin melanocytic lesions for biopsy," *Almanac of Clinical Medicine* **47(7)**, 662–668 (2019).

[5] Abramovich, S., Mashanskaya, A., Drobyshev, V., and Dolbilki, A., "Microcirculation in healthy people and patients with arterial hypertension," *Journal of Siberian Medical Sciences* **2** (2013).

[6] GRYGLEWSKA, B., NECKI, M., and CWYNAR, M. BARON, T. G. T., "Neurogenic and myogenic resting skin blood flowmotion in subjects with masked hypertension," *JOURNAL OF PHYSIOLOGY AND PHARMACOLOGY* **61 (5)**, 551–558 (2010).

[7] Williams, B., Mancia, G., and Spiering, W. e., "Esc/esh guidelines for the management of arterial hypertension," *European Heart Journal* **39** (2018).