

Laser Doppler Flowmetry in Diagnostics of Vascular Lesions in Lower Extremities

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Abstract—Laser Doppler flowmetry is a modern method of non-invasive microcirculation investigation. The aim of our study was to use this method in the examination of patients with secondary lymphedema of the lower extremities and obliterating atherosclerosis of lower extremities. In the analysis of the amplitude-frequency spectrum of secondary lymphedema patients we have identified remarkable changes. To describe the changes we used a special amplitude rate. In both of patients groups this rate was significantly ($p < 0.05$) different with the control group. So the marker phenomena of the amplitude-frequency spectrum of the LDF signal were identified. It is suggested that there is a limfodynamics contribution to the formation of the output signal of laser Doppler flowmetry. These data have fundamental meaning and are interesting for practical medicine, as they give an opportunity to further developments for the use of laser Doppler flowmetry in the diagnostics and monitoring the effectiveness of the treatment.

Keywords— laser Doppler flowmetry, secondary lymphedema of the lower extremities, obliterating atherosclerosis, non-invasive diagnostics.

I. INTRODUCTION

NOWADAYS diseases of blood and lymphatic vessels of lower extremities are widely spread pathologies. For example, WHO statistic says, that 10 % of humankind suffer from lymphedema of low extremities. Different diseases are accompanied by dysfunction of different types of vessels: arteries, veins, microcirculatory blood vessels or lymphatic vessels. Various types of vessel dysfunction need of different treatment. So it is actually to search a new method of non-invasive instrumental diagnostics, which can give the physician a possibility to ascertain the type of vessel under dysfunction before some strong clinical implications can be detected.

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A potential application point for such method is microcirculation because it is a site of arterial, venous and lymphatic systems integration [1], [2]. So pathological process in any system indispensably provokes some changes of microcirculatory blood stream characteristics. Thereby it is perspective to use a modern method of non-invasive investigating of microcirculation parameters like laser Doppler flowmetry. This method has high sensibility but absence of clear clinical application algorithms and result interpretation criteria makes difficulties for using of this method in clinical practice.

The aim of our study was to use this method in the examination of patients with secondary lymphedema of the lower extremities and obliterating atherosclerosis of lower extremities and detection of marker phenomena of every disease, which can be used as the interpretation criteria. In the context of this aim we have accomplished LDF-gramme registration among 2 groups of patients and control group and constructed amplitude-frequency specters of LDF signal.

II. MATERIALS AND METHODS

Our investigation was enveloped 30 patients of both sexes in the age of 27-81 years. According to clinical information all patients were divided into two groups: 10 patients with secondary lymphedema of the lower extremities and 10 patients with obliterating atherosclerosis of the lower extremities. The control group included 10 patients of the same age without pathology of arterial and lymphatic vessels of the lower extremities. Complex investigation included a clinical examination, an anthropometry and laser Doppler flowmetry.

Parameters of microcirculation were assessed through an LDF system Biopac MP 100 (Biopac instruments, USA) with original software and special skin transducer TSD 140 8*17 mm. LDF transducer was superimposed on the area above the medial ankle with the help of special adhesive disks. The laser Doppler investigation protocol included a 2-minutes long LDF-gramme recording on each lower extremity in a horizontal body position. Then a survivor was asked to stand up, and also a 2-minute long recording on both lower extremities was carried out.

In the course of output LDF signal processing amplitude-frequency spectra were constructed (with the help of the original software). Firstly the visual assessment and comparison of specters was carried out.

Amplitude-frequency spectrum has 3 characteristic areas:

1. *Slow-wave oscillations* (vasomotions) area (0.05-0.2 Hz). Slow-wave oscillations are caused by myogenous, neurogenus vessel tonus and endothelial factors effect;

2. *respiratory oscillations* area (0.2-0.4 Hz).
 Respiratory oscillations are caused by venous pressure gradient as a result of pulling action of the breast during respiratory movements;
3. *sphygmic oscillations (cardiorhythms)* area (0.8-1.6 Hz).
 These oscillations are caused by the heart working, the left ventricle propulsive action and sphygmic wave expanding. [3]

Zone of our attention was in slow-wave oscillation and cardiorhythms areas. For describing characteristic spectrum changes (harmonics) we used a special rate – the ratio of the maximum amplitude of the cardiorhythmic (pulse) harmonic (APmax) to the maximum amplitude of the slow-wave harmonic (ALmax).

In spite of situation that laser Doppler flowmetry are positioned as only a blood microcirculation investigating method [4] - [6], we think that lymphatic microcirculation also can take part in forming an output LDF signal because slowdown of lymph flow and changing of chemical structure of the lymph (increasing of albumins and globulins content), which are typical for secondary lymphedema [7], causes changing of optical characteristics of the lymph and makes it recognizable for laser Doppler flowmetry.

For statistical procession we have used paired non-parametric Mann-Whitney criteria, group differences are thought to be significant with 95% probability ($p < 0.05$).

III. RESULTS

Our investigations shows that patterns of amplitude-frequency spectrum of LDF signal, registered from different groups of patients are differ from each other and from the control group. These changes are regular and represent special forms of characteristic harmonics, which were named “marker phenomena”.

As it can be seen (Fig.1), in absence of lymphatic and arterial vessels diseases spectrum has gradual descending form, without sharp amplitude peaks in characteristic areas.

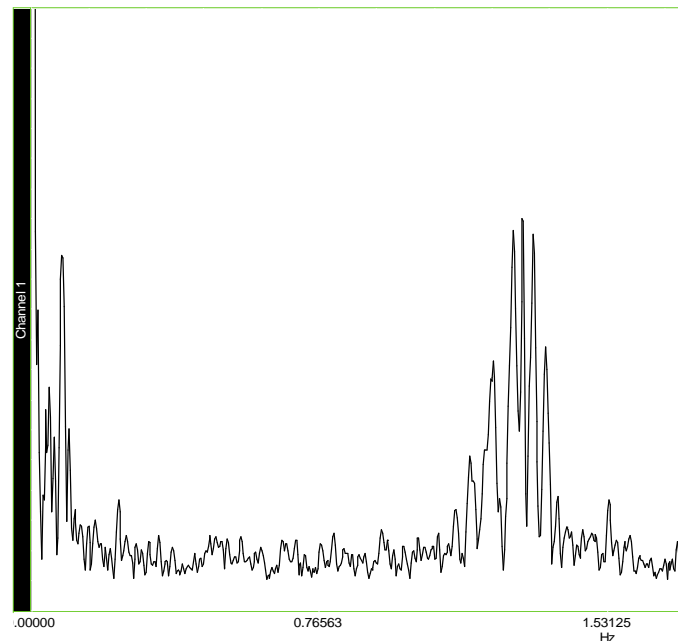


Fig. 2 Spectrum of the patient with secondary lymphedema (horizontal position)

It is remarkable that in case of secondary lymphedema of the lower extremities (Fig. 2) there are some changes in the slow-wave (left) and pulse (right) harmonics. These harmonics acquire a form of some sharp amplitude peaks above the general descending of the spectrum. In other words power of the slow-wave and pulse harmonics increases.

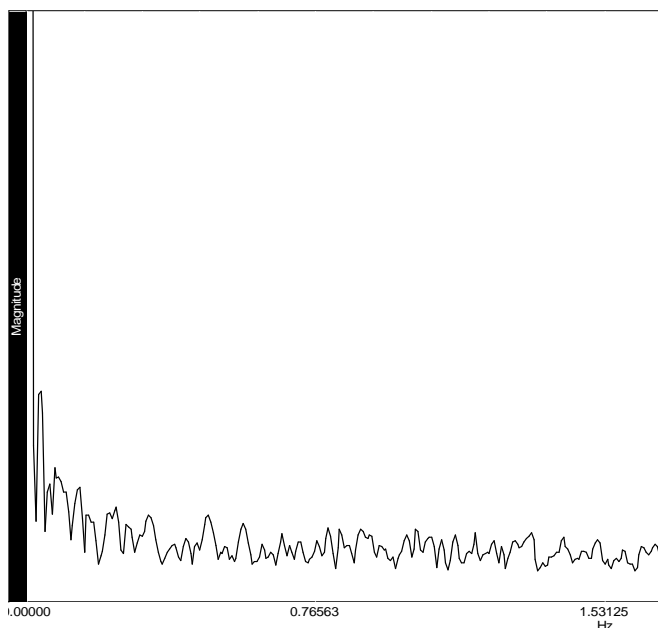


Fig. 1 Spectrum of the patient from the control group (horizontal position)

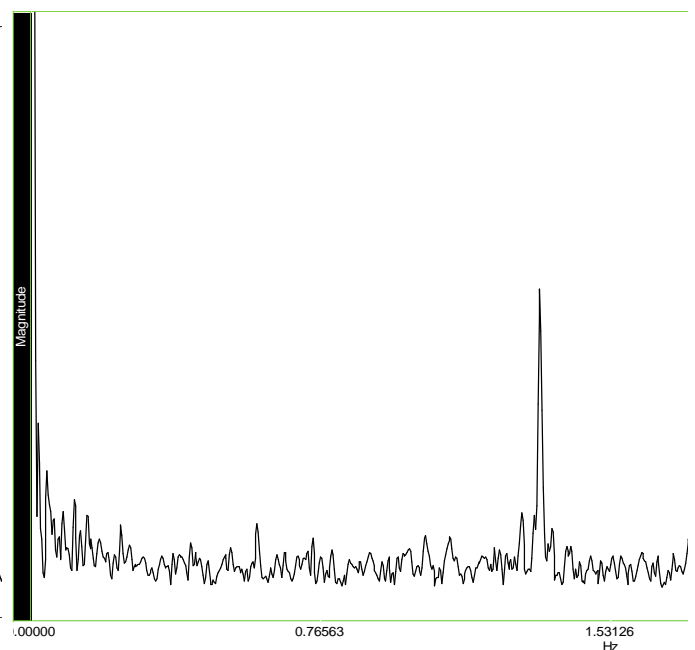


Fig. 3 Spectrum of the patient with obliterating atherosclerosis (horizontal position)

And in case of obliterating atherosclerosis (Fig.3) sharp amplitude peaks can be only detected in the pulse harmonic, while the slow-wave harmonic doesn't contain any special changes. We can observe increasing of power only of the pulse harmonic.

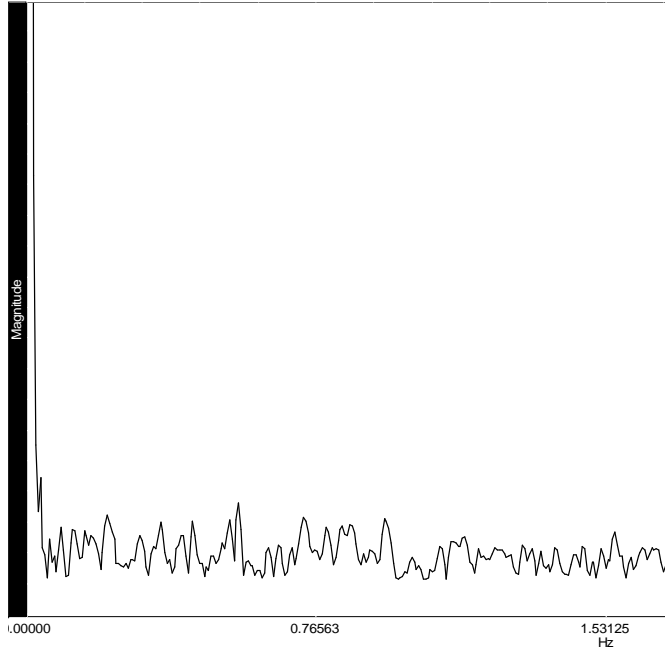


Fig. 4 Spectrum of the patient from the control group (vertical position)

Spectrum of LDF signal recorded in vertical position of patient's body (from the control group) (Fig.4) doesn't have any big differences in comparison with such spectrum of LDF signal recorded in horizontal position.

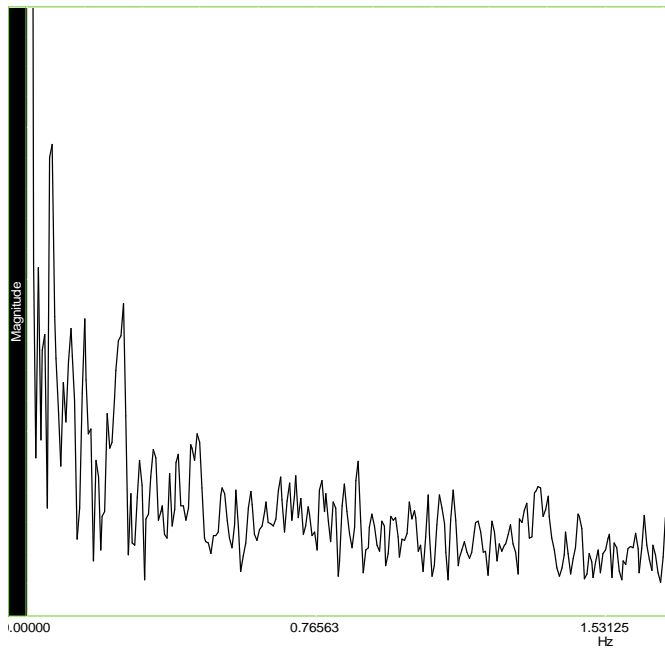


Fig. 5 Spectrum of the patient with secondary lymphedema (vertical position)

In case of secondary lymphedema of the lower extremities in vertical position specific slow-wave harmonic with characteristic sharp amplitude peaks persists (Fig. 5); power of this harmonic continues to be increased. But the pulse harmonic doesn't have any sharp peaks and its power increased.

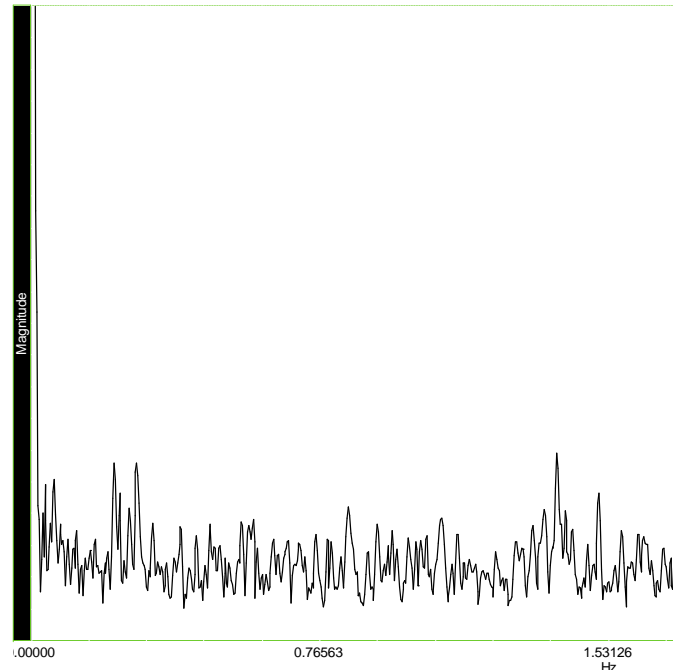


Fig. 6 Spectrum of the patient with obliterating atherosclerosis (vertical position)

Vertical position spectra of patients with obliterating atherosclerosis (Fig. 6) contain some amplitude peaks in sphygmoc oscillation area, but these peaks, in comparison with such peaks in horizontal position spectrum, are rather small and don't disturb a common gradual descending form such as in the control group.

Calculation a special rate – the ratio of the maximum amplitude of the pulse harmonic (APmax) to the maximum amplitude of the slow-wave harmonic (ALmax) showed (Fig. 7) that values of this rate both into secondary lymphedema and obliterating atherosclerosis groups of patients are significant ($p < 0.05$) more than in the control group. Significant differences of this rate between secondary lymphedema and obliterating atherosclerosis were not found.

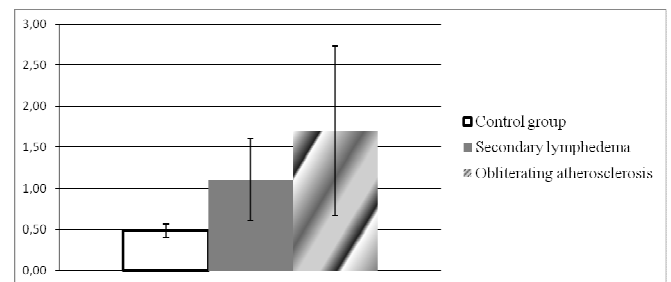


Fig. 7 Ratio APmax / ALmax

Based on our results we put forward a hypothesis that full output LDF signal is not only formed by microcirculatory bloodstream, but microcirculatory lymph flow also takes part in output LDF signal formation. It is confirmed by the fact of presence of characteristic harmonics with sharp amplitude peaks in slow-wave oscillations area at patients with secondary lymphedema of lower extremities. Secondary lymphedema accompanies with slowdown of lymph flow and changing of chemical structure of the lymph, with increasing content of albumins and globulins, which forms large colloid particles. Linear dimensions of these particles are closely to 40-50 nm. All these factors change optical properties of the lymph that can be a cause for appearance of characteristic harmonic (marker phenomenon) in slow-wave area of amplitude-frequency spectrum. In this way one can think about the presence of special *lymphatic component* in formation of LDF output signal.

IV. SUMMARY

On the ground of results we got, following conclusions were made:

1. Laser Doppler flowmetry is a high perspective method of non-invasive diagnosis of blood and lymphatic vessels dysfunctions;
2. Characteristic harmonics with sharp amplitude peaks are marker phenomena of secondary lymphedema and obliterating atherosclerosis of the low extremities;
3. It is rightfully to put forward a hypothesis that lymph flow also takes part in forming of output LDF signal.

These data have fundamental meaning and are interesting for practical medicine because they give a capability of next development of using laser Doppler flowmetry in diagnosis of blood and lymphatic vessels pathologies and monitoring of the effectiveness of producible treatment.

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