

УДК 615.471.03:616.073

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OPTIC-ELECTRONIC SYSTEM FOR EVALUATION OF COLLATERAL CIRCULATION OF LOWER EXTREMITIES LASER

The paper evaluated the diagnostic value of laser photoplethysmography when examining patients with chronic lower limb ischemia. A statistical analysis of the research results was made, and diagrams of relationship between the degrees of ischemia and blood flow are presented.

Keywords - occlusive disease of lower extremity arteries, collateral circulation, a survey laser photoplethysmography.

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ОПТИКО-ЕЛЕКТРОННА СИСТЕМА НА ОСНОВІ НИЗЬКОІНТЕНСИВНОГО ЛАЗЕРА ДЛЯ АНАЛІЗУ КОЛАТЕРАЛЬНОГО КРОВОНАПОВНЕННЯ

У статті представлено результати використання лазерного фотоплетізографа при обстеженні пацієнтів з хронічною ішемією нижніх кінцівок. Статистичний аналіз результатів дослідження було зроблено і представлено діаграми взаємозв'язку між ступенем ішемії і периферійним кровонаповненням.

Ключові слова - оклюзійна хвороба артерій нижніх кінцівок, колатеральний кровообіг, лазерна фотоплетізографія.

INTRODUCTION. Non-invasive diagnostic methods with optical registration and transformation of biomedical information extensive have been extensively developed for the last few years. Laser photoplethysmography (LPPG) relates to one method of non-invasive optical diagnostics peripheral circulation.

Method can improve the reliability of the control and peripheral circulation diagnostics and identify the effects on the autonomic nervous system, can serve for for evaluation of sympathetic innervation of the skin, can be used in the diagnostics of Raynaud's disease, early forms of atherosclerosis, thrombosis, etc.. This method can controll the depth of spinal anesthesia (simultaneous registration of vascular reaction taken from finger and toes). Besides, PPG has additional diagnostic and prognostic value in the study of many cardiovascular and neurological diseases, that are the most common causes of death and disability in young age [1, 2, 3]. Therefore, effective processing of photoplethysmographic information is very important/

The purpose is the evaluation of laser photoplethysmography's (LPPH) diagnostic value in examination of patients with chronic ischemia of lower extremities.

MATERIALS AND METHODS. There were examined 82 people in total. 18 patients have been diagnosed on the ischemia of the II degree, 8 – on IIIA, 12 – on IIIB, and 15 – on IV. The key group consisted of 29 individuals without symptoms of obliterating diseases concerning lower limbs' arteries. Their age ranged from 18 to 82 years. It was conducted physical examination and LPPH. The latter has allowed to evaluate the microcirculation (local circulation) in the area of research. Physical examination was carried out by means of "Wosteo" product. On the foundation of received photoplethysmogram (the high-amplitude pulsatile (Fig. 1 a), the low-amplitude pulsatile (Fig. 1, b), nonpulsatile (Fig. 1, c) it was determined the nature of blood flow.

Based on these data the sensitivity, specificity, and predictive LPPH value in diagnostics of lower limb arteries' occlusion diseases were calculated. Sensitivity was defined as a sign of positive sign of the research conducted among the sick people, specificity – a negative sign among healthy ones, predictive value – as the probability of the disease presence (absence), knowing the results of the analysis [6].

SUBSEQUENT RECOGNITION. Having examined the key group, the pulse was determined on all the levels of the lower limbs, the foot skin was warm, pale pink with fast red dermographism (8-26 sec). Manteuffel and Laignel-Lavastin's test did not exceed 4 sec. Th reactive wrist hyperemia occurred for 8.2 sec at a pressure of 100-140 mm Hg. The foot reactive hyperemia occurred for 4-14 sec, at a pressure of 100-160 mm Hg. The high-amplitude (28 people) and low-amplitude (1 person) pulsing blood flow was registered by LPPH.

13 patients noted the chilliness of foot, paresthesia, hypothermia of foot skin in the II stage of ischemia. They had pale skin, slow red (30-48 sec) dermographism, predisposition to hypertension. The Manteuffel and Laignel-Lavastin's test was 2.6 sec. Walking distance equaled 140-240 m. The wrist reactive hyperemia occurred for 4-10 sec at a pressure of 110-170 mm Hg. The reactive foot hyperemia occurred for 17-73 sec, at a pressure of

70-120 mm Hg. The ratio of the blood saturation index on the foot to the analogous index on the wrist was $-0,93 \pm 0,04$. Having been examined by LPPH, it turned out that 12 patients had high-amplitude pulsatile blood flow and 6 - the low-amplitude pulsatile blood flow.

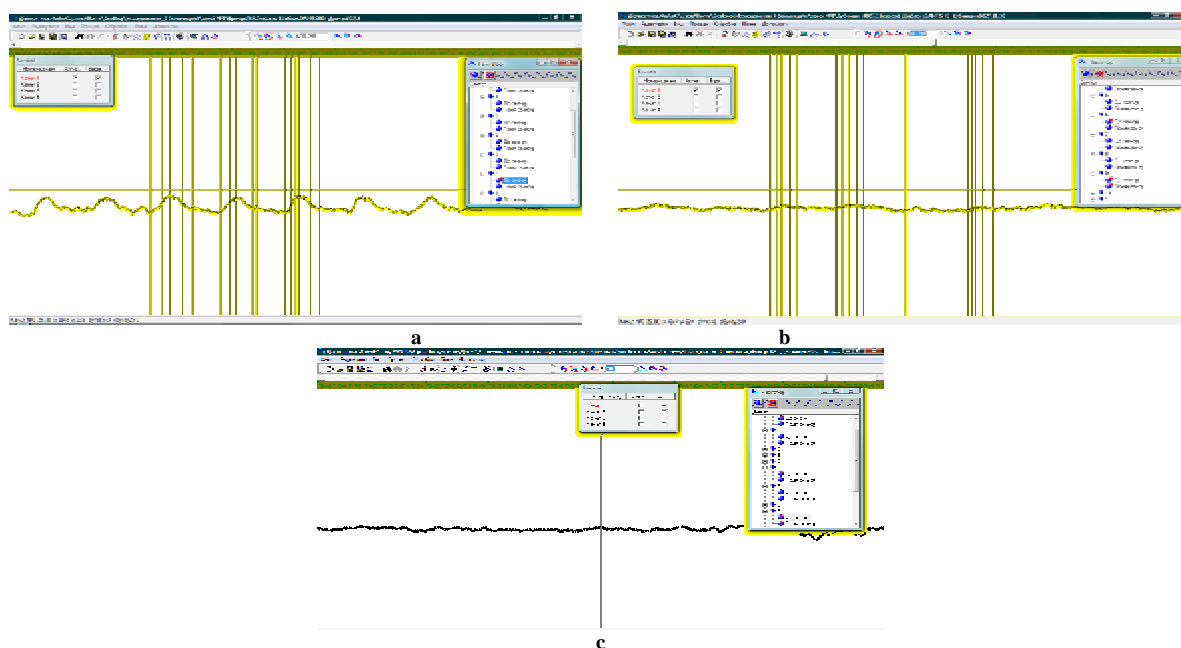


Fig.1. Determining the flow of blood:
a) high-amplitude pulsatile –b; low-amplitude pulsatile; c) nonpulsatile

Patients with stage IIIA ischemia always felt cold and paresthesia in the foot and pain when they rest – this forced one to lower leg 1-3 times a night. The foot's skin was cold and pale with a white dermographism. The Manteuffel and Laignel-Lavastin's test was 6-10 sec. Walking distance equaled 25-50 .The reactive wrist hyperemia occurred at 4-12 sec at a pressure of 110-170 mm Hg, on foot - for 62-98 sec at SP below 60 mm Hg. There were recorded 5 patients with a low-amplitude pulsatile blood flow and 3 – with nonpulsatile after LPPH .

DISCUSSION OF RESULTS. In general physical data reflects the state of regional hemodynamics adequately. However, hypo- or hyperesthesia was often observed when diabetic neuropathy. The patches of necrosis while maintaining a foot pulse have been noticed. Walking distance might be shortened if the pathology of the musculoskeletal system was found. A test on dermographism is too much subjective, in particular, it depends on the stamping strength. It is uncomfortable to evaluate the results of Manteuffel and Laignel-Lavastine tests if somebody has a purple, pale or pale bluish skin. In the latter case you should pay attention to the turgor tissues and the quickness of hole extinction. Nevertheless, there is too much subjectivity in the last words. Physical examination does not allow us to carry out a proper evaluation of collateral circulation.

Reactive hyperemia is a sensitive test. Endothelium synthesizes vasodilators, anhioprotektors, (nitric oxide, etc.) vasoconstrictors, prothrombotic factors (thromboxane A et al.) and plays an important role in regulating vascular reaction and hydraulic arteries' resistance, free radical oxidation, intravascular thrombosis, inflammatory and autoimmune reactions [6, 9]. Endothelial are sensitive to the speed of blood flow. The blood flow velocity is much greater than on the initial level while reactive hyperemia. Hence, the production of nitric oxide is increasing [8, 9]. Positive changes in the indices have been registered among the patients with the preserved collateral circulation. Perfusion hyperemia value increases by 150-250%. Patients who have arterial occlusion on the basis of endothelial disfunction suffer from interval rasing till flushing. Interval duration equals the quantity of blocks and depends on the seriousness of ischemia. The smaller the maximum significance of perfusion and degree of increase relatively to the initial level is, the more difficult decompensation of regional circulation is .

There is a spasm of arterioles and precapillary sphincters and increase peripheral resistance with the ischemia the II degree. With ischemia of the III-IV degree atony of vessels occurs (until paresis), including arteriovenular shunts, deep microcirculation disturbances and irreversible tissue changes [2, 3, 7]. With critical ischemia the initial level of blood flow was high, but not pulsatile, that demonstrates the violation of myogenic tone and paresis of capillary sphincters in patients with diabetic angiopathy combined with atherosclerosis [5].

The graphical dependence of foot-hand coefficient on the degree of ischemia is shown in Fig. 2.

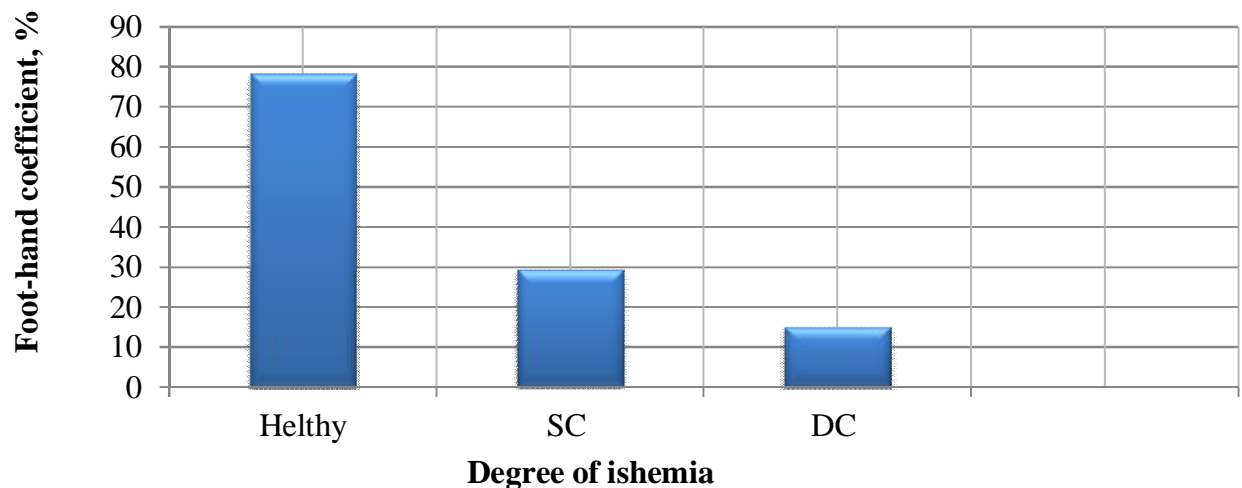


Fig. 2. Dependence of foot-hand coefficient on the degree of ischemia

CONCLUSION. As a result of experimental and clinical studies 7 amputations were made, 1 lower extremity was saved. Other patients were assigned to individual treatment and medical supervision.

So, LPPH method allows to determined pulsatility of blood flow in different areas of the foot and lower leg, the degree of compensation and conservation perspectives limb and of amputation level. The informativity of method is more than 90%. LPPH is the highly informative method to evaluation the pulsatility of blood flow in a specific area. The high pulsatile blood flow is the most informative parameter.

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