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Author works in Vinnytsia National Technical University, Ukraine. In 2012 she received a PhD degree. In 2018 she was awarded with the Award of the Verkhovna Rada of Ukraine for the most talented young scientist in the field of fundamental and applied research and scientific and technical developments.

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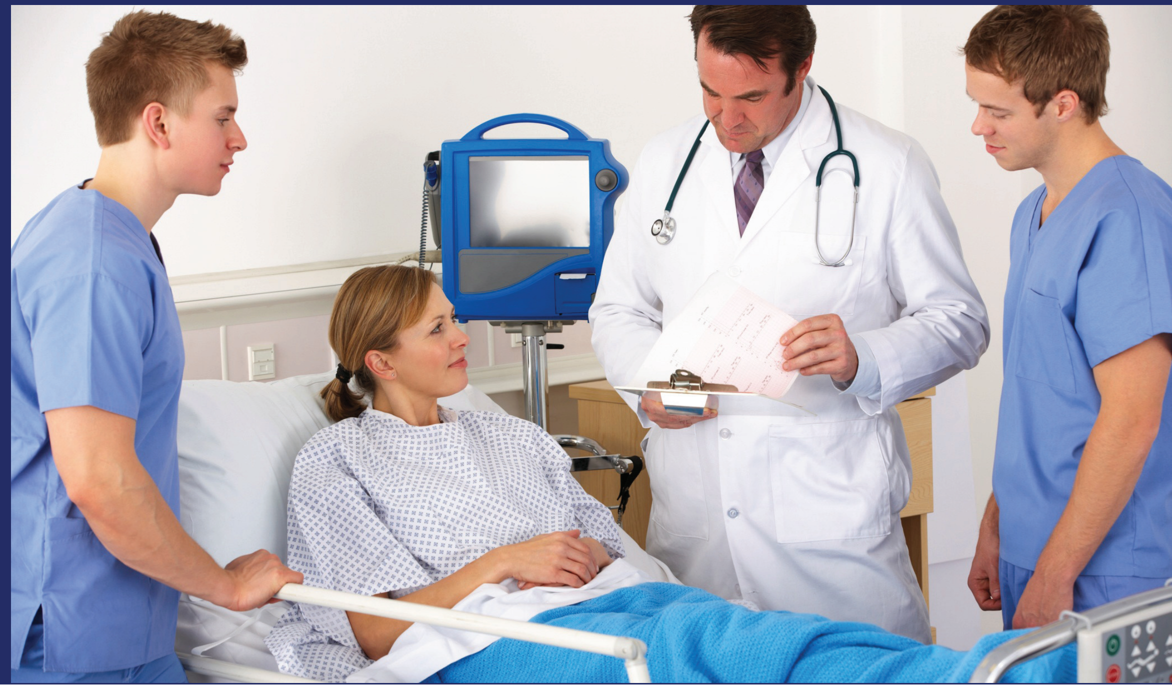

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Sergiy Pavlov

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Tetiana I. Kozlovska, Sergiy V. Pavlov

OPTOELECTRONIC MEANS OF DIAGNOSING HUMAN PATHOLOGIES ASSOCIATED WITH PERIPHERAL BLOOD CIRCULATION

Monograph

The monograph deals with the construction of optoelectronic means of diagnosing the state of peripheral circulation. New formulas have been obtained for calculating the parameters of optical radiation depending on the thickness of the biological tissue and the constructive construction of the optical sensor. Were conducted investigations of the peripheral blood circulation of the abdominal wall using developed device and integrated evaluation of collateral circulation of lower extremities.

CONTENT

INTRODUCTION

The human health directly depends on the state of peripheral blood circulation. Today, the problem of violations of the peripheral blood circulation is becoming more important because rapid development of industry and technology progress caused the negative influence on the environment, including human health and the many diseases associated with disorders of the peripheral blood circulation began to appear in more younger age [1, 2].

Therefore, for timely and qualitative diagnosis of such disorders the modern medicine uses non-invasive methods. These methods allow providing painless and non-destructive control of affected areas. The most perspective among them are optical methods that allow conducting painless and non-destructive control of affected areas.

One of the promising methods of studying peripheral circulation is a photoplethysmographic method, which allows the use of contactless sensors, resulting in no compression of the vessels, which eliminates the circulation of blood in the investigated area. The method is based on photoelectric measurements of both passed and reflected light radiation in the red and infrared ranges. This method is used in most cases in vascular diseases for the objective assessment of the state and degree of violations of regional blood flow, vascular tone, to control the effectiveness of treatment used with subsequent laser and photon methods of vascular function restoration, for differential diagnosis of organic and functional vascular diseases. Particularly valuable information is given by symmetric studies of affected and unaffected vessels of the same patient and PPG dynamics under the influence of functional loads and during pharmacological tests [1, 2, 4, 5].

Modern medical technology has its own diagnostic functional advantages, but existing devices have low reliability of diagnosis and high sensitivity to artifacts. The use of devices with higher technical performance is limited by their high cost and a number of contraindications for the patient. Therefore, to solve the problems of diagnosis of peripheral circulation, it is necessary to develop simple devices with wide functional capabilities, high accuracy and reliability [1, 2, 6, 7].

The development of medical techniques, algorithms, software and technical means for diagnosing microcirculation and peripheral circulation on the basis of modern optoelectronic and laser technologies, which ensure high operability, accuracy and non-invasive of research is a rather promising direction [1, 2, 7].

Therefore, the task of creating advanced methods for recording of optical radiation and diagnostic tools for peripheral blood circulation disorders, based on modern optoelectronic technologies, is relevant.

1. PHYSICAL-MATHEMATICAL MODEL OF OPTICAL RADIATION INTERACTION WITH BIOLOGICAL TISSUES

Human skin is a complex multilayer medium that contains blood vessels, through which is passed continuous blood flow. The main factors that affect on the distribution of laser radiation in biological tissues are the skin color, the presence of inhomogeneities and hairy. And all of them complicate the research of the processes of interaction of optical radiation with human skin. There are many mathematical and physical models that allow representing and describing of these processes and each of them is focusing on a specific case of studying [1].

The mathematical description of the light scattering and absorption processes can be made in two ways: by using analytical theory based on Maxwell's equations, and using transport theory. The main disadvantage of analytic theory is complexity of getting the accurate analytical solutions. Transport theory describes the interaction of laser radiation with tissue, and considers the transfer of photons by scattering and absorbing medium, without using Maxwell's equations [1, 3].

Due to development of methods of laser diagnostics were expanded opportunities for studying of peripheral blood circulation. The use of lasers is based on the light interaction with biological tissues [1, 2], such as scattering, reflection and absorption. These processes depend on the pigmentation of the skin, blood composition and collagen fibers structure that determine the photons distribution in investigated area of the tissue. The absorption coefficient of the skin is mainly determined by the water and such pigments as melanin, bilirubin, β-carotene and hemoglobin [7]. Melanin is the base pigment and it is the main epidermal chromophor. The absorption coefficient of the epidermis and the corneal layer is determined by the melanin absorption. In the Figure 1 is represented absorption spectrum of melanin in the epidermal layer of human skin [9, 10, 12].

The one of important value is the optical density (OD) which is calculated as:

$$OD = \mu_{\mathrm{mel}} \cdot h_{\mathrm{e}}, \qquad (1)$$

where μ_{mel} – the coefficient of the absorption of melanin, h_e – the thickness of the epidermis layer [1]

The amount of melanin depends on the type of skin and can be changed from 1,5% to 43%.

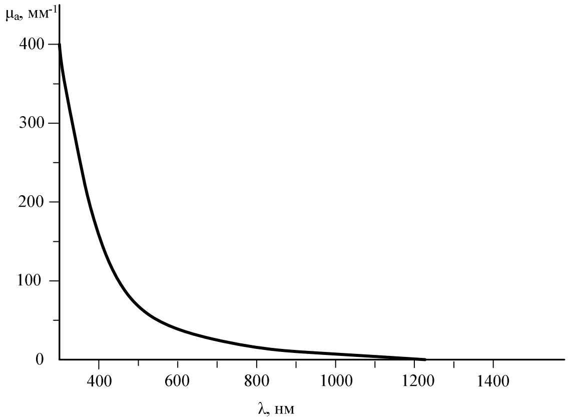

Fig. 1 Absorption spectrum of melanin [9, 10]

The dermis structure of the skin is different from the epidermis structure and its scattering is stronger on the shorter wavelengths. As the penetration depth of radiation in dermis at different wavelengths depends on the scattering, penetration of longer wavelengths is more deeper than shorter. This is due to presence of melanin, which is contained in dermis and it absorbs shorter wavelengths. Propagation of the optical radiation in the different skin layers is shown in Fig. 2. [4].

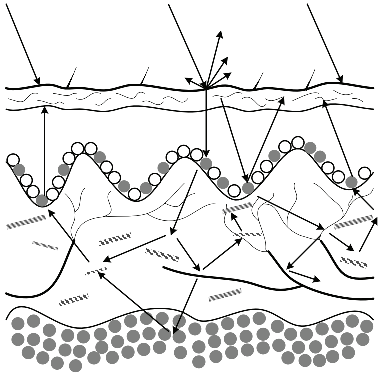

Fig. 2 Propagation of the optical radiation in the human skin [4]

The light that irradiates the skin area, takes different paths in its layers. Part of the incident radiation is reflected from the skin surface because there is refractive index difference in the corneal layer and the air and it is called as total internal reflection. Remain, is not reflected radiation from the skin surface (about 93-95%), passes into the epidermis layer. In the epidermal layer radiation is almost not scattered but is absorbed by melanin. When the radiation passes through the dermal layer, is occurred the multiple scattering by collagen fibers and absorption by melanin.

The peak absorption of hemoglobin occurs on 280, 420, 540 and 580 nm with threshold wavelengths 600 nm. The main feature of such molecules as hemoglobin and melanin is their complex threshold structure is located in 400-600 nm range. But in the near infrared region their absorption is strongly attenuated. The most deeply radiation passes into the tissues on the therapeutic window region (600 – 1300 nm) as a result of weak absorption and strong scattering. On the wavelengths over 1500 nm the water is the main absorption center [6].

In the Fig. 3 is represented dependence of the coefficient of the absorption and the depth of penetration of laser radiation on the biological tissue properties. As we can see from the figure the maximum depth of penetration is in therapeutic window region. That is why diode lasers, radiation of which is in the red and near infrared region is used for photoplethysmographic investigations.

By the electromagnetic field elastic-charged particles start moving. When the oscillation frequency of particles coincides with the frequency of the waves is a significant absorption due to resonance. When the frequencies of particles do not coincide with the wave frequencies, radiation is scattered. One of the reasons of the scattering is inhomogeneity of the refractive index at the microscopic level [2, 11, 12].

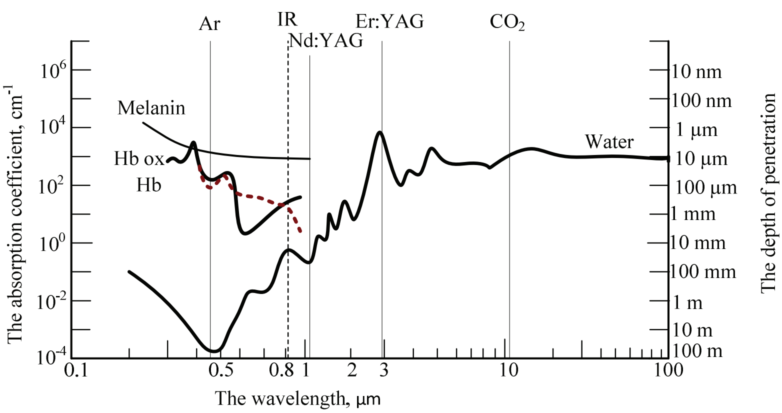

Fig. 3 Dependence of the absorption coefficient and the depth of penetration of the water, hemoglobin and melanin on the wavelengths