УДК: 61:340.6:[535.361+535.51]

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UP-TO-DATE OPTIC METHODS OF INVESTIGATION IN DIAGNOSTICS OF MYOCARDIAL ISCHEMIC PROCESSES

Key words: *lazer polarimetry, myocardium, ischemia.*

Abstract. *The work is devoted to the analysis of the existing polarizational methods of investigation of the body's tissue and determination of effectiveness when using lazer polarizational methods of the research of ischemic damages taking acute myocardial ischemia as an example. The necessity of the search and development of the newest methodics has become conceptual having analyzed the mortality structure of the population and traditional methods of diagnostics of ischemic processes in the cardiac muscle. Having explored the possibilities of polarizational methodics of biotissue research we have chosen lazer polarizational methods of investigation as more prospective for the search and development of new diagnostics criteria of ischemic damages of a human tissues. The research showed the efficacy of these methodics for improvement of ischemic processes diagnostics and also revealed the possibilities for differential diagnostics of pathological processes in human myocardium.*

Sudden death in consequence of the cardiovascular system diseases takes a significant place in the structure of death reasons in forensic medical examination. According to the WAO data the rate of a sudden cardiac death within a week for 1 ml of the population constitutes 1,6 casses [1,4]. In the structure of causes of the population general mortality in the developed countries 20% fall on acute coronary insufficiency (ACI) and approximately 30% - on other forms of ischemia heart disease (IHD). Specific characteristics of death owing to ACI is its suddenness: patients die before they are provided medical care. As to the gender differences, ACI more often occurs in men, however, distribution does not depend on profession and occupation [1]. The rate of ACI development causes a set of problems connected not only with providing medical care to the patients but complicacy of diagnostics, since macroscopic changes, as a rule, do not have time to acquire pathognomonic signs [5] for a short time of ischemia.

The above cited data confirm actuality of renovation and improvement of the methods of determining acute ischemia foci. And, taking into consideration their use in the field of forensic medicine, they must additionally possess a number of distributive signs, to which objectivity of estimation that served as the established fact for law enforcement bodies should be referred to first of all.

Changes of myocardium at acute coronary insufficiency

Clinically (between an episode of acute retrosternal pain and necrosis development) there is a rather wide interval that is indicate as ACI. To date, the diagnostic signs of ACI at forensic-medical examination of the cadaver are: signs of the blood supply disturbance in the great vessels of the heart, microcirculatory injuries and penetration of the vascular walls, structural-functional state of the muscular tissue and changes of myocardium stroma.

There is a small quantity of macroscopic AID of the human myocardium that is acute local ischemic dystrophy. In particular, the following signs are distinguished: flabby myocardium of irregular pulsevolume with possible dilatation of the left ventricle cavity [1, 6, 7]. But these signs are not pathognomonic and can

occur in case of other kinds of cardiac pathology. It is quite natural that such a small quantity of criteria and their insufficient specificity (flabby myocardium occurs also at hypertrophic cardiomyopathy, fatty degeneration of the heart, both of nonheritable etiology, and at thesaurismoses; in case of myocarditis myocardium is not only flabby, but maculosus too) do not permit a doctor to make a diagnosis of AID only on their basis.

It is known that at cardiac muscles ischemia medium suboxidation results in inhibition of actomyosin ATPase properties, Ca2+ forcing out from connections with troponin and actomyosin dissociation. Change of actomyosin ATPase properties is one of the main causes of the myocardium contraction decrease in case of ischemia.

An increase of Ca2+ level in cytosol is accompanied with enzymes' activation, causing injuries of membrane lipid structure and leads to the subsequent increase of its permeability,enzymes leaving from the cells and larger energy deficiency, that is, succession of the events, leading to the cells necrosis and destruction, is developed.

Energy metabolism arrangement is very quickly affected on a state of contraction apparatus of the cardiac muscular cells - myofibrils.

The following changes are observed in them;

-contractural damages that affect pathological total or focal myofibrils contraction;

-intracellular myocytolysis characterized by myofibril focal lysis;

-myofibril distribution arising as a result of simultaneous mosaic contraction of sarcoma groups and lysis of myofibril areas that didn't contract.

All these myofibril changes determine tinctorial sarcoplasm properties of the damaged cardiomyocytes.

But the majority of diagnostics methods enables to record changes in ischemia zone only in 6-8 hours from its beginning.

In such situation it should be better to find the keys of solving the problem not on macro- but microscopic level of myocardiocytes structure. In particular, changes of energy balance have an effect on the function of the most power-consuming system of cardiomyocyte-actino-myosin complex, right away.

The structure of action-myosin complex enables it to fulfill its function of energy and electromechanical conjugation with maximum effectiveness.

The main part of myofibril proteins is presented with G-actins, polymerized to F-actin and thick threads (fibre) of myosin type II. It is impossible to ensure a work of full value without troponin T (it is responsible for binding with one tropomyosin molecule), troponin C (it binds ion Ca2+) and troponin I (binds actin and inhibits contraction). Framework function is carried out by nebulin, α-actinin, desmin and vimentin.

In general, sarcomere has unique properties of liquid crystal.

Let us consider the structure of biological tissue (BT). The whole BT complex can be presented as totality of fibrillar protein structures, forming its unique structural-functional organization. The significant peculiarity of these fibrillar proteins is their clear regulating, that gives them properties of liquid crystals. Liquid crystals are known to be substances that simultaneously manifest fluidity of liquids and crystals, molecules of which are in a definite way regulated. As a result, there exist anisotropy of mechanical, electric, magnetic and optic properties of this class substances.

We suggest to use well approved and introduced into medical practice polarizational methods of investigation in order to study BT changes on this level. Thus, the methods of diagnostics of pathological changes by means of using monochrome lazers acquire spreading, in particular, in forensic medicine.

By means of lazer polarimetry it is possible to reveal anisotropy of optic properties. Their administration enables to investigate pathological changes on nano-level - the level of liquid crystals and biological analogs of liquid crystals. At the same time, when usual methods of histological investigation are uneffective, lazerpolarimetric methods permit not only to diagnose ACI, but can allow to differentiate it with other pathological conditions.

Terms, biological analogs of liquid crystals are used for the description of those biological systems which are subjected to the laws of transparent crystal configurations, but lost their liquid nature. Biological membranes are the example of biregringent of biological materials, which can be real liquids. The model of molecular organization of biological membrane is shown in Fig. 1.

A constant description of biological polymers forming liquid crystals, is that they consist of twisted screw-like formations (fig. 2)

Chains are interlaced and form three-fold spiral. If they are packed into Z-like layers, the system of the lined up deepenings is formed. The next layer of three-fold spiral can get any of the steady positions. They can be (a) parallel with initial layer in deepenings between three-fold spirals or (b) in deepenings, which lie under the angle to the initial layer.

Thus, it is possible to ascertain that geometric construction of extracellular matrix of the main BT-

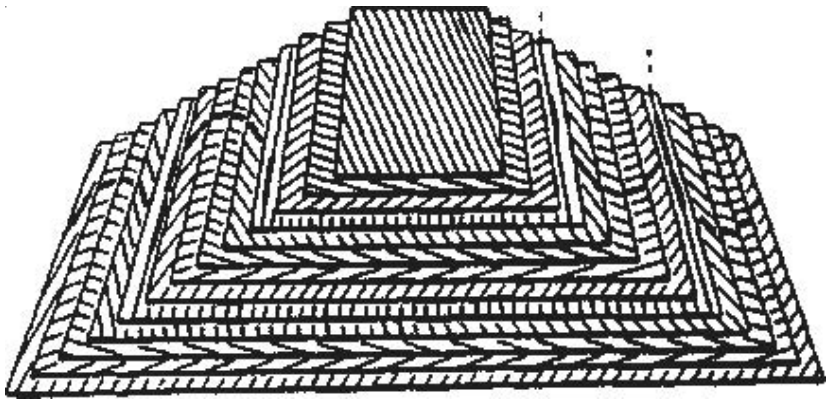
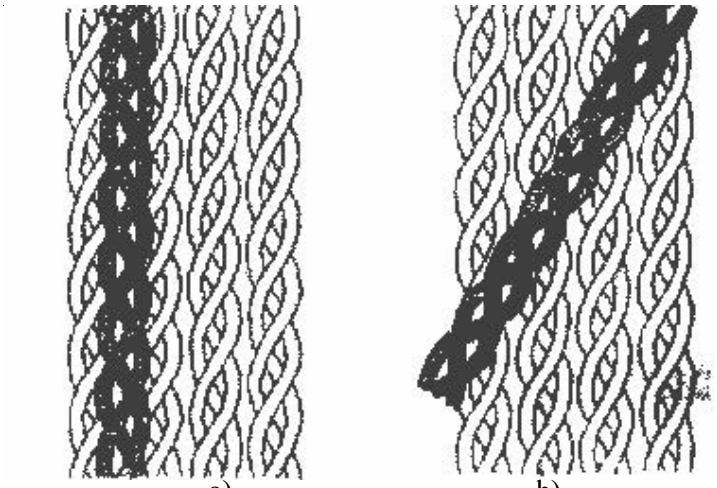


Fig. 1. Distorted stratified model.



a) b)

Fig.2. Possible relation between molecular constituent (a) and angular rotation (b) (Nevil model).

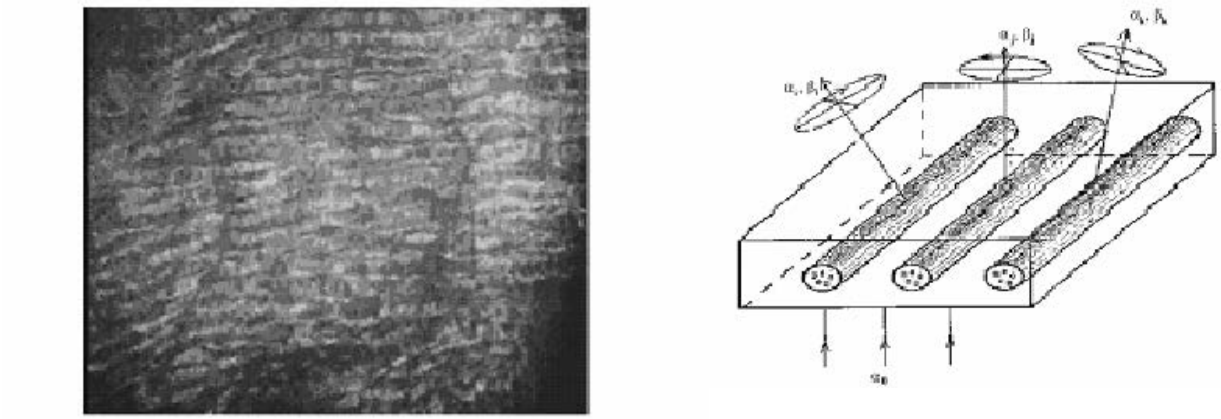
types is a total combination of fibrillar proteins structure, which have properties of liquid biological crystals.

The whole variety of the morphology of BT and human organs can be characterized from the united optico-crystal positions - the process of conversion of lazer eradiation parameters by total combination of optically uniaxial biological crystals.

On the basis of information concerning to BT morphological structure the following model is suggested. Biological tissue consists of two phases: amorphous and optically anisotropic, which in its turn consists of two level of organization - crystal and architechtonic.

Coaxial fibrils, that form collagenous elastin and myosin organic fibres can be attributed to the crystal level of BT organization.

Thus, muscular tissue is spatially regulated system of protein fibers which consist of optically isotropic actin and anisotropic myosin.



a) b)

Fig. 3. Layer of human muscular tissue (a) and its optic model (b). α_0 - polarization azymuth of probing lazer wave; α_i, β_i- azymuth and elliticity of polarization of image points.

On the basis of aforesaid, we suggest the complex of lazer polarimetric methods [2, 3, 6, 7] to diagnose AID of the myocardium.

Let us consider the possibilities of ACI diagnostics and carrying out differential diagnostics with adjacent pathology - chronic ischemia heart disease (CIHD) on the example of veivlet-analysis of the fractal structure map ellipticity of polarization of lazer images of the human myocardium.

It is known that distribution of polarization ellipticity $\beta(x)$can be arranged in line by means of veivlet-function $\psi_{ab}(x) = \psi(ax\text{-}b)$, that is made up by displacement b and dimensions - a [7]:

$$\beta(x) = \sum_{a,b=-\infty}^{\infty} C_{ab}\Psi_{ab}(x) \quad (1)$$

Coefficients of such disorder are determined by the following manner:

$$C_{ab} = \int \beta(x)\Psi_{ab}(x)dx \quad (2)$$

The result of the veivlet-transformations (1, 2) of one-dimensional distribution $\beta(x)$ is two-dimensional five of coefficients $W\beta(a,b)$, which are defined according to the following ratio:

$$W(a,b) = \frac{1}{|a|^{1/2}}\int_{-\infty}^{+\infty} f(\beta)\Psi\left(\frac{x-b}{a}\right)dx \quad (3)$$

We used MHAT - function - the second derivative of Gausov function [6] as a veivlet-function.

To evaluate distribution $W\alpha(a,b=1,2,\ldots m)$ at different scales of α veivlet-function ψ total combination of their statistical moments 1 - 4-th orders [3] was calculated:

$$M_1 = \frac{1}{m}\sum_{i=1}^{m}|W_i|,\quad M_2 = \sqrt{\frac{1}{m}\sum_{i=1}^{m}W_i^2},\quad M_3 = \frac{1}{M_2^3}\frac{1}{m}\sum_{i=1}^{m}W_i^3,\quad M_4 = \frac{1}{M_2^4}\frac{1}{m}\sum_{i=1}^{m}W_i^4. \quad (4)$$

As a result, calculation (ratio 1-3) of two-dimensional totality of veivlet-coefficients of lachk - line of icsels of light-sensitive digital camera ground (fig. 4) was carried out.

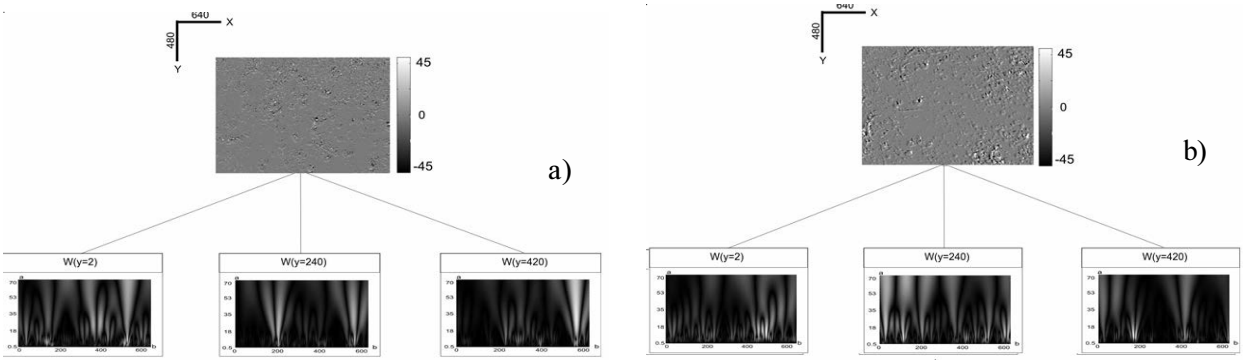


Fig. 4. Distributional of veivlet-coefficients $W(a_{min};b=k1\div km)$ of polarization map ellipticity $\beta(m$ x $n)$ of polarization of myocardium lazer images at AIC (a) and CIHD (b) for different lines CCD-camera (k=2; k=240; k=420).

Then we determined logarithmic dependencies of distributions power spectral $logJ(W)\text{-}log(d^{-1})$ on three scales (a_{min}=2μm; a_{min}=10μm; a_{min}=30μm) MHAT-veivletof polarizational map lazer images of myocardium layers of the dead due to ACI (fig.5a) and CIHD (fig. 5b).

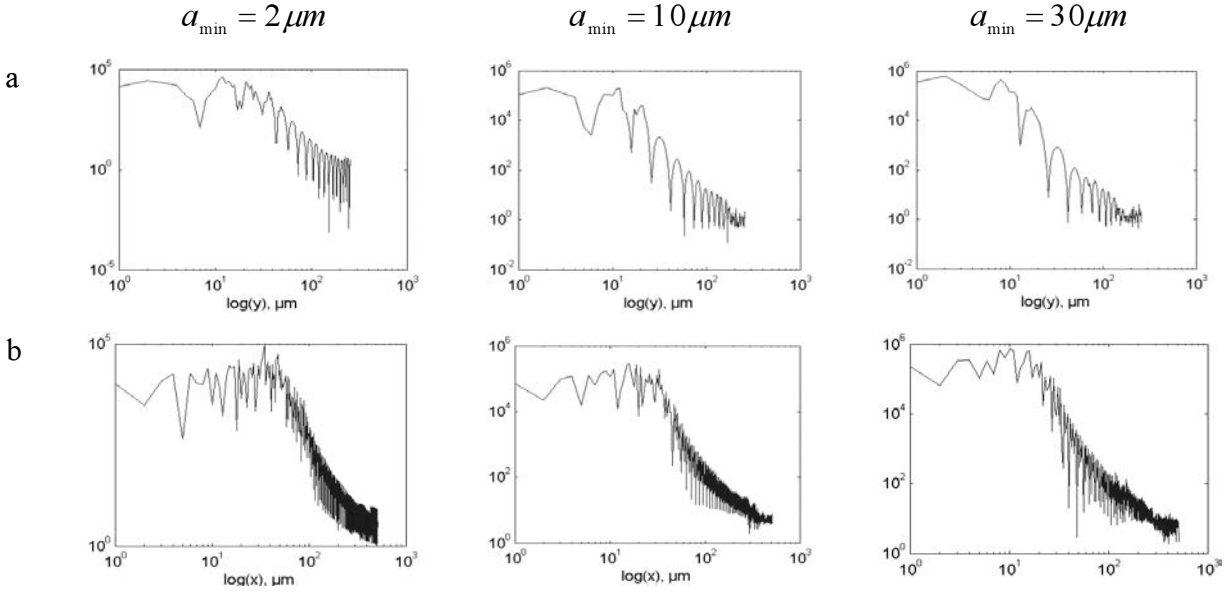


Fig. 5. Logarithmic dependencies $logJ(W)\text{-}log(d^{-1})$ of spectral power of veivlet-coefficient distributions $W[(a_{min}$= 2μm; 10μm; 30μm)$;b=k1\div km)]$ of polarizational chart of polarization ellipticity of the myocardium lazer images of both groups.

From the data obtained it is seen that logarithmic dependencies of spectral power of veivlet-coefficient distributions of polarizational chart of polarization ellipticity of the myocardium sections of both groups are individual for each of MHAT - veivlet.

The revealed peculiarities of homogenous structure of veivlet-coefficient distributions of lazer images polarizational maps of myocardium tissues sections, to our mind, are connected with chaotic state of phase displacements, which occur at the expense of birefringent changes of polycrystal myosin fibrillar structures in case of ACI on middle (a_{min}=10μm;) and large (a_{min}=30μm;) scales MHAT - veivlet.

Objectively such process is characterized by values and ranges of changes of statistical moments changes of 1-4 thorders of logarithmic dependencies $logJ(W)$-$log(d^{-1})$ at different scales of MHAT - veivlet (table 1).

Table 1

Statistical moments of the 1-4th orders of logarithmic distributions spectra of pluralities capacity of veivlet coefficients of polarization charts of polarization ellipticity of myocardium sections lazer images of both groups

Chronic ischemic heart disease			Acute coronary insufficiency		
a_{min}	M_j		a_{min}	M_j	
a_{min}=2μm	M_1	0,76±0,005	a_{min}=2μm	M_1	0,65±0,0042
	M_2	0,18±0,002		M_2	0,24±0,003
	M_3	1,08±0,0032		M_3	7,14±0,0049
	M_4	1,32±0,0033		M_4	10,72±0,005
a_{min}=10μm	M_j		a_{min}=10μm	M_j	
	M_1	0,68±0,0048		M_1	0,59±0,004
	M_2	0,23±0,0034		M_2	0,27±0,0038
	M_3	0,89±0,003		M_3	4,17±0,0043
	M_4	1,08±0,0031		M_4	6,71±0,0046
a_{min}=30μm	M_j		a_{min}=30μm	M_j	
	M_1	0,57±0,0038		M_1	0,53±0,003
	M_2	0,29±0,004		M_2	0,33±0,0049
	M_3	0,71±0,0029		M_3	1,45±0,0038
	M_4	0,98±0,003		M_4	2,73±0,0038

P ≤0,005

Comparative analysis of statistical structure of logarithmic dependencies of veivlet-coefficients' distributions of polarizational maps of ellipticity $\beta(m \times n)$ of lazer images of myocardium tissue sections of the dead due to ACI and CIHD has revealed considerable values of statistical moments of the 3th and 4th orders of logarithmic dependencies of spectra capacity distributions $W_{[(amin=2\mu m;\ 10\mu m;\ 30\mu m);b=k1\div km)]}(\beta)$ on all scales of MHAT-veivlet.

Conclusions

1. Lazerpolarimetric methods of studying human biotissue structure are the most prospective among the whole range of polarizational investigations today.

2. An increase of index of birefringent partial myosin crystals regulated according to the optic axes directions is revealed due to ischemia conditions. Moreover, such transformation of polycrystal structure starts from small dimensions of the structural elements of polycrystal myocardium network.

3. Polarizationally index increase of birefringent partial myosin crystals is manifested in the formation of compound asymmetric distributions of ellipticity of polarization of the corresponding myocardium lazer images, having prospects of the subsequent introduction of the given method into practice for the diagnostics improvement of acute coronary insufficiency.

4.This method is efficient for carrying out differential diagnostics of the pathological processes.

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СУЧАСНІ ОПТИЧНІ МЕТОДИ ДОСЛІДЖЕННЯ В ДІАГНОСТИЦІ ІШЕМІЧНИХ ПРОЦЕСІВ МІОКАРДА

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Резюме. Робота присвячена аналізу існуючих поляризаційних методів дослідження тканин організму та визначення ефективності використання лазерних поляризаційних методик дослідження ішемічних уражень, на прикладі гострої ішемії міокарда.

Ключові слова: лазерна поляриметрія, міокард, ішемія.

СОВРЕМЕННЫЕ ОПТИЧЕСКИЕ МЕТОДЫ ИССЛЕДОВАНИЯ В ДИАГНОСТИКЕ ИШЕМИЧЕСКИХ ПРОЦЕССОВ МИОКАРДА

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Резюме. Работа посвящена анализу существующих поляризационных методов исследования тканей организма и определению эффективности использования лазерных поляризационных методик исследования ишемических поражений, на примере острой ишемии миокарда.

Ключевые слова: лазерная поляриметрия, миокард, ишемия.

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Clin. and experim. pathol.- 2014.- Vol.13, №4 (50).-P.76-81.

Надійшла до редакції 05.11.2014
Рецензент – проф. В.Т.Бачинський