

4.5. Wavelet analysis of myocardium polarization images in problems of diagnostic of necrotic changes

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4.5.1. Introduction

In the series of research works the possibility of polarimetry diagnostic [1-19] of optically anisotropic layers of biological tissues [20-22] and fluids [23-37] is demonstrated.

This research aims to study fundamental potentiality of ischemic heart disease and acute coronary insufficiency died patients myocardial tissue microscopic images wavelet analysis for polarization-correlation mapping.

4.5.2. Theory of the method

T.Setala, Ya.Tervo and A.T.Friberg [30,31] proposed to describe the correlation structure of the stationary distributions of the fields of complex amplitudes of laser light converted by optically anisotropic biological layers, one can use the mutual spectral density matrix.

We have generalized this theory to the case of phase anisotropy of biological tissues. For this purpose, analytical expressions for the phase of the first and second complex two-point parameters of the Stokes vector are determined.

$$\left\{ ArgS_1 = arctg \left[\frac{\sin(\delta_2 - \delta_1)}{ctg\rho_1 ctg\rho_2 + \cos(\delta_2 - \delta_1)} \right] \right\}. \quad (4.5.1)$$

$$\left\{ \text{Arg} S_2 = \text{arctg} \left[\frac{\sin(\delta_2 - \delta_1)}{\text{ctg} \rho_1 \text{ctg} \rho_2 - \cos(\delta_2 - \delta_1)} \right] \right\} \quad (4.5.2)$$

In the approximation of weak phase modulation, the expressions (4.5.1) - (4.5.2) acquire the following form

$$\left\{ \text{Arg} S_1 = \text{arctg} \left[\frac{(\delta_2 - \delta_1)}{1 + \text{ctg} \rho_1 \text{ctg} \rho_2} \right] \right\} \quad (4.5.3)$$

$$\left\{ \text{Arg} S_2 = \text{arctg} \left[\frac{(\delta_2 - \delta_1)}{\text{ctg} \rho_1 \text{ctg} \rho_2} \right] \right\} \quad (4.5.4)$$

4.5.3. Materials and methods

Measurement of the coordinate distributions values is carried out in the experimental arrangement of Stokes-polarimeter, the optical scheme of which is shown in Fig. 4.5.1.

$\text{Arg}(S_{i=1}(\Delta x; \Delta y))$ and $\text{Arg}(S_{i=2}(\Delta x; \Delta y))$ were calculated by the following ratios

$$\left\{ \text{Arg} S_1 = \text{arctg} \left(\frac{\left[\sqrt{I_0(r_1) I_{90}(r_2)} \sin \delta_2 + \sqrt{I_0(r_2) I_{90}(r_1)} \sin \delta_1 \right]}{\left[\sqrt{I_0(r_1) I_{90}(r_2)} \cos \delta_2 + \sqrt{I_0(r_2) I_{90}(r_1)} \cos \delta_1 \right]} \right) \right\} \quad (4.5.5)$$

$$\left\{ \text{Arg} S_2 = \text{arctg} \left(\frac{\left[\sqrt{I_0(r_2) I_{90}(r_1)} \cos \delta_2 - \sqrt{I_0(r_1) I_{90}(r_2)} \cos \delta_1 \right]}{\left[\sqrt{I_0(r_2) I_{90}(r_1)} \sin \delta_1 + \sqrt{I_0(r_1) I_{90}(r_2)} \sin \delta_2 \right]} \right) \right\} \quad (4.5.6)$$

Here I_0 and I_{90} - the intensities at the orientation of transmission plane of polarizer 0° and 90° ; δ_i - phase shifts between the orthogonal components

of the amplitude of the laser radiation in the points with coordinates r_1 and r_2 .

It follows from the analysis of the obtained relations (4.5.5) - (4.5.6) that the SCP phase $Arg(S_{i=1,2,3,4}(\Delta x, \Delta y))$ carries information about their birefringence ($\delta(x, y)$).

4.5.4. Brief description of the research objects

Optically thin (attenuation coefficient $\tau \pi 0.01$) samples of histological sections (geometrical thickness $l = 25\mu m \div 30\mu m$ $0.0093 \leq \tau \leq 0.0099$) of myocardium biological tissues of internals of two statistically significant (37 samples each) groups.

Histological sections of biological tissues of rat's internal were produced by the standard technique in freezing microtome.

4.5.5. Experimental results and discussion

The coordinate distributions of the phase and the corresponding histograms of the phase of large-scale (Fig. 4.5.1) and small-scale (Fig. 4.5.2) polarization correlation parameters of the Stokes vector of images of the histological sections of the myocardium with IHD (fragments (1), (2)) and ACI (fragments (3), (4)) were submitted.

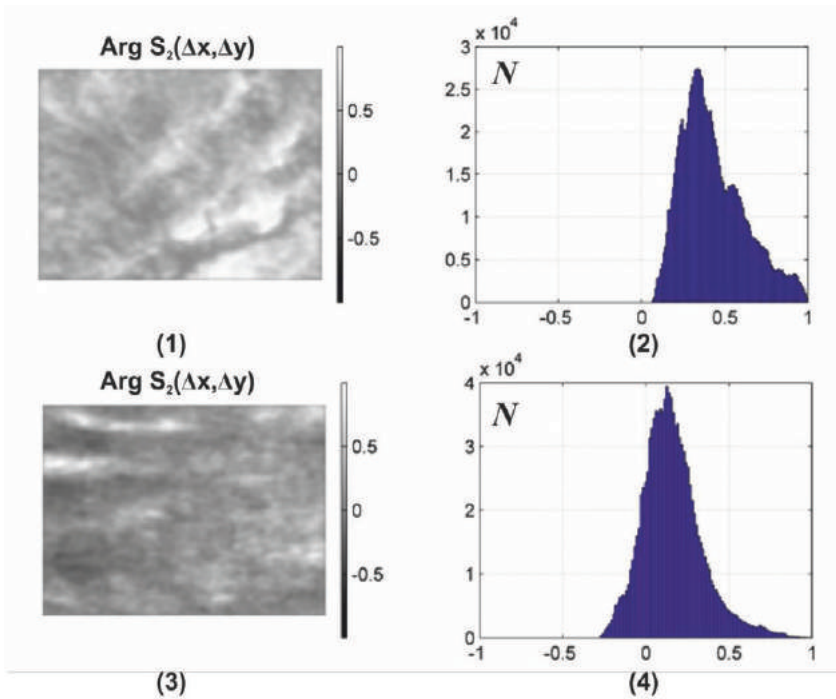


Fig. 4.5.1. Polarization maps of the phase of the second parameter of the Stokes vector (fragments (1), (3)) and histograms of the corresponding distributions (fragments (2), (4)) of the large-scale birefringence structure of the histological sections of the myocardium with IHD (fragments (1), (2)) and ACI (fragments (3), (4)).

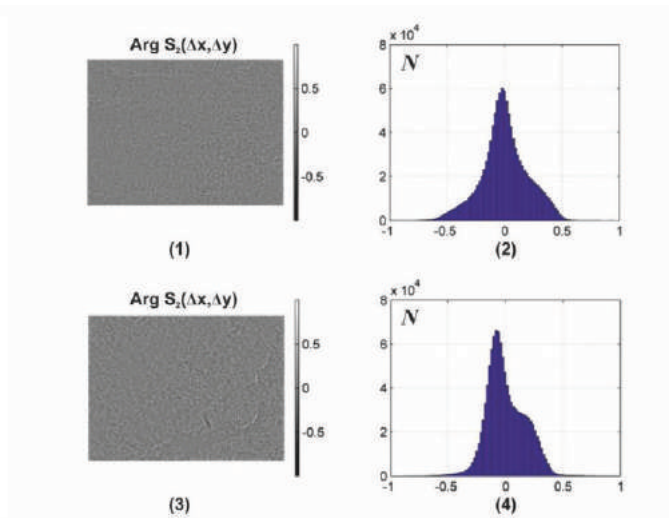


Fig. 4.5.2. Polarization maps of the phase of the second parameter of the Stokes vector (fragments (1), (3)) and histograms of the corresponding distributions (fragments (2), (4)) of the low-scale birefringence structure of the histological sections of the myocardium with IHD (fragments (1), (2)) and ACI (fragments (3), (4)).

4.5.6. Intergroup statistical, correlation and fractal analysis of the phase distributions of SCP-maps

The results are presented in Table 4.5.1.

Table 4.5.1 Statistical parameters SCP phase maps

$Arg(S_2(\Delta x; \Delta y))$	IHD (low)	ACI (large)	IHD (low)	ACI (large)
z_1	0.13 ± 0.0056	1.21 ± 0.015	0.23 ± 0.013	0.81 ± 0.054
z_2	0.23 ± 0.015	0.33 ± 0.017	0.21 ± 0.014	0.28 ± 0.015
z_3	0.43 ± 0.034	0.23 ± 0.017	0.87 ± 0.056	0.47 ± 0.035
z_4	1.12 ± 0.033	1.21 ± 0.047	1.98 ± 0.096	1.79 ± 0.093

The analysis of the data presented in Table 4.5.1 showed:

- individual for each type of biological tissue values of statistical $Z_{i=1;2;3;4}$, parameters describing the coordinate distributions $Arg(S_2(\Delta x; \Delta y))$;
- the values of statistical moments of the 3rd ($Z_3(Arg(S_2))$) (by 2.15 – 3.6 times) and 4th ($Z_4(Arg(S_2))$) orders (by 1.23 – 2.56 times).

4.5.7. Conclusion

A new method of wavelet-analysis of the coordinate distributions of the phase of "two-point" Stokes-vector parameters of polarization-inhomogeneous images of histological sections of biological tissues of myocardium is suggested and analytically substantiated.

The comparative analysis of the objective statistical analysis of distributions of polarization Stokes-vector parameters of polarization-inhomogeneous images of histological sections under study demonstrated the excellent accuracy ($Ac \phi 90\%$) of differential diagnostics of changes in optical anisotropy of myocardium by the wavelet method.

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