Statistical Analysis of Vector-Parametric Polarization Images of the Polycrystalline Component of Biological Tissues with Varying Degrees of Necrotic Changes

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ABSTRACT

The results of a statistical analysis of the distributions of characteristic values of the Stokes vector fourth parameter (crystallization parameter - CP) of the digital vector-parametric microscopic image of healthy spleen and with spleen with sepsis histological sections are presented. We determined the statistical significance of differentiation of vector-parametric maps of the microscopic image of histological sections of rat spleens from control group 1 and research groups 2–4 with different severity of septic pathology. The most diagnostic-sensitive statistical criteria for differentiating vector-parametric maps of microscopic images of histological sections of the spleen are established

Keywords: polarization, Stokes vector, differential diagnosis, necrotic changes.

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1. Introduction

Development and experimental tested of a new digital technique for objective differential diagnosis of septic severity by statistical analysis of vector-parametric polarization images of histological sections of the internal organs of laboratory rats.

To establish diagnostic relationships between the data of the method of polarization vector-parametric mapping of microscopic images of histological sections of the internal organs of laboratory rats and septic changes, the following model scheme for the formation of vector-parametric images was used.

2. Structural and logical scheme and design of the study

Our investigation aims to develop principles of differential diagnosis of the severity of the septic process by using digital methods of vector-parametric polarization mapping of microscopic images of histological sections of internal organs and blood films of laboratory rats [1-3].

This technique is based on the establishment of diagnostically relevant relationships between the distributions of the number of characteristic values of the polarization parameter of the Stokes vector [4-7] of microscopic images of histological sections of internal organs and blood films of laboratory rats and the severity of the septic process.

To achieve this goal, we used a set of methods Stokes-polarimetric microscopic examination, parametric, statistical and informational analysis [8-11] of septic changes in the polycrystalline structure of histological sections of internal organs and blood films of laboratory rats, which are characterized by structural-logical scheme (Fig. 1)

Differential diagnosis of the severity of the septic process by methods of vector-parametric mapping of microscopic images of histological sections of internal organs and blood films of laboratory rats
Model of amorphous-crystalline structure of biological preparations of laboratory rats
Method of polarization vector-parametric mapping of microscopic images of histological sections of internal organs and blood films of laboratory rats
Vector-parametric microscopic images of histological sections of internal organs and blood films of laboratory rats
Statistical analysis of distributions of the number of characteristic values of the Stokes vector parameter of digital microscopic images of histological sections of internal organs and blood films of laboratory rats
Criteria for differential diagnosis of the severity of sepsis in laboratory rats
Operational characteristics of the method of vector-parametric mapping of microscopic images of histological sections of internal organs and blood films of laboratory rats
Sensitivity, *Se* Specificity, *Sp* Accuracy, *Ac*

Fig. 1. Structural and logical scheme and design of the study by vector-parametric mapping of microscopic images of histological sections of internal organs and blood films of laboratory rats.

The structure of the study of the polycrystalline component of biological preparations of internal organs and blood of rats in the differential diagnosis of the severity of the septic state using digital Stokes polarimetric microscopy consists of the following experimental and analytical actions:

1. Representative samples of histological sections of the internal organs of the following groups of rats are formed:
   - ❖ Intact rats - "control" group 1 (39);
   - ❖ Sick rats (sepsis - easy form) - "research" group 2:
   - duration 12 hours. (39 samples) - “research” subgroup 2.1;
   - duration 48 hours. (39 samples) - “research” subgroup 2.2;
   - ❖ Sick rats (sepsis - average form) - "research" group 3:
   - duration 12 hours. (39 samples) - “research” subgroup 3.1;
   - duration 48 hours. (39 samples) - “research” subgroup 3.2.

2. Within each of the four groups for each sample of the biological product is carried out:
   - measurement of the coordinate distribution of the magnitude of the fourth parameter of the Stokes vector (crystallization parameter - CP) in pixels of a digital microscopic image;
   - determination of the distribution of the number of characteristic values $\{N(S_4 = 0) = N_1(0), N_2(0),...., N_{m-1}(0); N_m(0);$
   - calculation of the set of statistical moments of the 1st – 2nd orders characterizing the average S and dispersion D of distributions $\{N(S_4 = 0) = N_1(0), N_2(0),...., N_{m-1}(0); N_m(0);$.
3. For the obtained group sets (average S and dispersion D), average magnitudes and fluctuations of the statistical moments of the 1st – 2nd orders are determined.
4. For all groups of biological preparations, a cross-analysis of the statistical reliability of the data is performed and objective criteria for differential diagnosis of the presence of the septic process and its severity are determined by Stokes polarimetric microscopy.

3. Experimental results and their discussion

In a series of fragments of fig. 1 and fig. 2 are shown the vector-parametric maps (fig. 1) and the distribution of the number of characteristic CP values (fig. 2), which are determined for digital microscopic images of rat spleen histological sections from group 1.

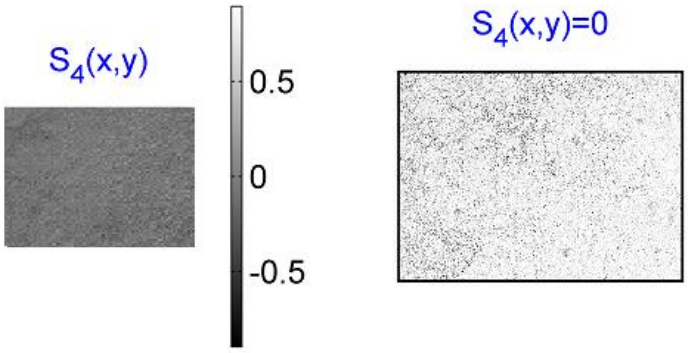

Fig. 2. Vector-parametric map (fragment (2)) PC (fragment (1)) of microscopic images of histological sections of the spleen of rats from group 1

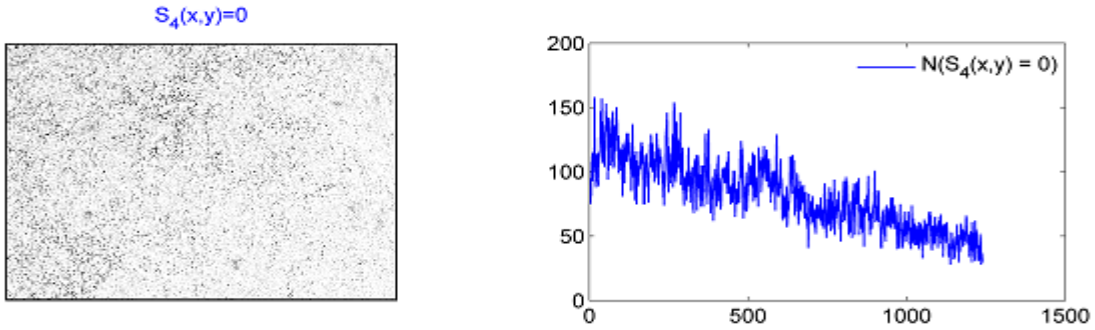

Fig. 3. Vector-parametric map (fragment (1)) and distribution of the number of characteristic values (fragment (2)) of the PC at the points of microscopic images of histological sections of the spleen of rats from group 1.

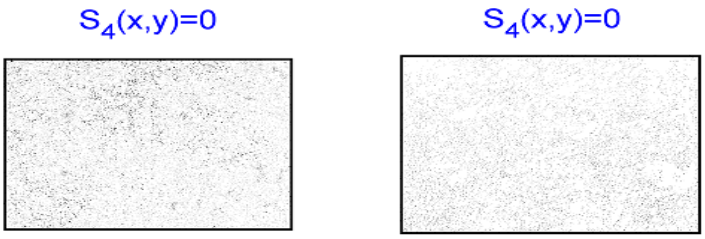

Fig. 4. Vector-parametric maps (fragments (2), (3)) PC (fragment (1)) of microscopic images of histological sections of the spleen of rats from group 2.1 (fragment (2)) and group 2.2 (fragment (2)).

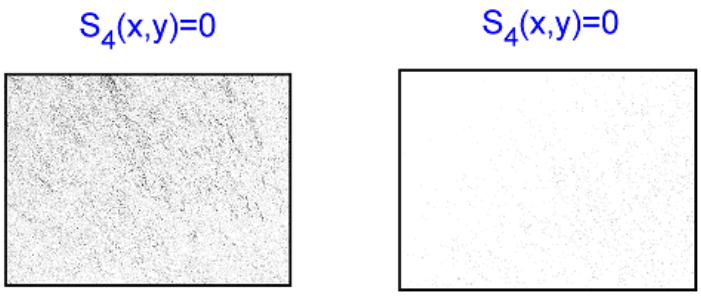

Fig. 5. Vector-parametric maps (fragments (2), (3)) PC (fragment (1)) of microscopic images of histological sections of the spleen of rats from group 3.1 (fragment (2)) and group 3.2 (fragment (2))/

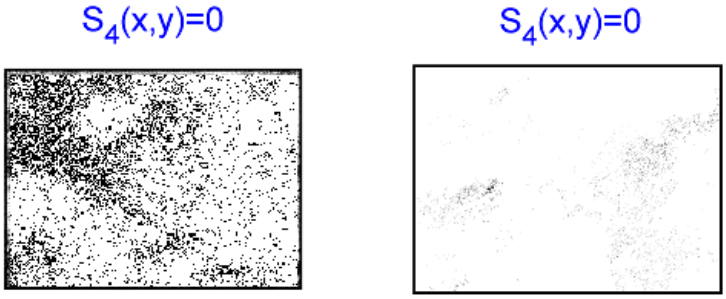

Fig. 6 Vector-parametric maps (fragments (2), (3)) PC (fragment (1)) of microscopic images of histological sections of the spleen of rats from group 4.1 (fragment (2)) and group 4.2 (fragment (2)).

Table 1. Statistical parameters of vector-parametric maps of microscopic images of histological sections of the spleen

Groups	**Group 1 Intact** $(n=39)$	**Group 2** **Sepsis (easy)** $(n=39)$		**Group 3** **Sepsis (average)** $(n=39)$	
Duration	**0 hours**	**2.1** **(12 hours)**	**2.2** **(48 hours)**	**3.1** **(12 hours)**	**3.2** **(48 hours)**
Average, *S*	101,3 ± 2,67	75,2 ± 1,45	56,9 ± 1,04	44,7 ± 0,81	28,1 ± 0,62
Dispersion, *D*	25,8 ± 0,54	19,6 ± 0,49	13,4 ± 0,32	8,7 ± 0,26	6,2 ± 0,21

Table 2 are presented the results of determining the balanced accuracy of the method of vector-parametric polarization mapping of histological sections microscopic images of healthy spleen and sick sepsis rats.

Table 2. Balanced accuracy of differential diagnosis of sepsis severity by vector-parametric maps of images of histological sections of the spleen

Parameters	**Balanced accuracy**, *Ac*,%			
Groups	**"1 – (2,3,4)"**	**"2-3"**	**"2.1 – 2.2"**	**"3.1-3.2"**
Average, *S*	**96**	**93,6**	**94,8**	**90,7**
Dispersion, *D*	**93,6**	**92,3**	**90,7**	**85,3**

Conclusions

The following ranges of maximum balanced accuracy of differential diagnostics were identified:

- intact - patients **"1 - (2,3,4)"** - excellent quality diagnostic test $Ac = 93{,}6\% - 96\%$;
- easy - average grade **"2-3"** - excellent quality diagnostic test $Ac = 92{,}3\% - 93{,}6\%$;
- internal group easy degree "**2.1 - 2.2**" - excellent quality diagnostic test $Ac = 90{,}7\% - 94{,}8\%$;
- internal group average degree **"3.1 - 3.2"** - excellent quality diagnostic test $Ac = 90{,}7\%$;

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