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Morphology of chordae tendianeae of atrioventricular valves hearts newborns and infants in terms of laser polarimetry

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ABSTRACT

The paper studied the morphological features of the structure and polarization properties of tendon tissue strings atrioventricular valvular of newborns and infants on histological sections. Analysis of the obtained results showed high diagnostic sensitivity of statistic moments of coordinate distributions of matrix elements of both types of chordae tendianeae of atrioventricular valves hearts tissue to the changes of optical-geometric structure.

Keywords: morphology, tendon strings, heart valves, polarimetry

1. INTRODUCTION

Despite the large number of scientific papers devoted to the heart [1-2], this time to think both home and foreign authors there are many different controversial issues. They are associated with morphological structural features of valvular heart disease and its individual structural components: valves, tendon strings mastoid muscle and fibrous ring [1-2].
All structures are large valvular morphofunctional load, ensure normal hemodynamics, cardiac output structure and biomechanics of the heart as a whole. Damage to one of these components valvular heart leads to a structural reorganization of the endothelium and connective tissue components, which in turn leads to disruption of hemodynamic, anatomical changes and valvular disease in general [1-2].
As you know, tendon strings are fibrous strands that look like thin threads and normally interconnect the top mastoid muscle and valves and valve affecting bioethics atrioventricular heart valves , so cardiologists and cardiac surgeons there is an increased interest in structural of tendon strings as their topography and structure affect the normal functioning of valvular heart disease and to predict cardiohaemodynamic [2].
According to the classification of tendon strings of the heart they are classified as boundary, i.e, those that are attached to the edges of the leaves, leaf, spot fixing being lower surface of leaf valve (facing the cavity of the ventricle) and abnormally arranged strings.
Thus detailed knowledge of the structural features of normal tendon strings atrioventricular valvular involved in the formation of valvular morphology will assess key components of valvular heart disease, will enable clinical diagnosis correctly set and understand the mechanisms of congenital heart disease.
However, the results of long-term studies have shown that neither the clinical and laboratory data, even when careful analysis nor highly informative tools available survey methods do not provide adequate information or the true depth of the damage nor the reversibility of the process. In this regard, there is a need to find and develop new techniques for the study of pathological changes in the human body.
Currently the physical methods are promising in this respect using optical correlation techniques to studying the phenomenon of light scattering, provides objective data of the changes in the studied tissues and more accurately determine the time interval elapsed from the date of death of man. The use of lasers in biomedical diagnosis led to the development of another research direction - laser polarimetry, which aims to study the structure imaging of biological tissues. Currently there is actual development of the study of biological objects, which will be used in predefined mathematical parameters that make the study independent of the experience of medical staff. Laser polarimetry provide new information on the morphological structure of biological tissues. Therefore, it is appropriate to study the characteristics of polarization images of biological tissue valvular heart disease.

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2. THE MORPHOLOGY OF CHONDRAE TENDIANEAE OF ATRIOVENTRICULAR VALVES HEARTS NEWBORNS AND INFANTS

According to the macroscopic study of tendon strings newborns and infants were divided into three groups: the first group was made - boundary tendon strings that are attached to the free edges of the valve cusps, the second group included - sash tendon strings that are attached to the ventricular surface of the valve leaflets, the third group was basal tendon strings that are attached to the base of leaves.

Total number of tendon strings are attached to the cusps of atrioventricular valves of the heart in both age groups ranged from 30 to 80. To the free edge of the front wings both valves from 11 to 25 tendon strings were connected in infants amount of tendon strings was slightly higher from 10 to 27. To the free edge of the rear wings infants 7 - 18 tendon strings in infants from 9 to 30 were connected. To the free edge Septal leaf tricuspid valve in neonates and infants attached the same number of tendon strings 5 - 12. By the middle of the ventricular surface of the cusps of atrioventricular valves newborn connected 10 - 20 tendon strings and infants 6 - 21. To the base of valve leaflets in neonates and infants is also fitted different amounts of tendon strings in infants from 5 to 15 and in infants from 7 to 18.

Number of tendon strings which are gone from the mastoid muscle was different in neonates and infants minimum number of strings that depart from the mastoid muscle was 1 and the maximum 12. Number of tendon strings depends on the number of mastoid muscle - the more its mastoid muscle, the greater the amount of tendon strings departed from them (Fig. 1). In a small number of mastoid muscle, a decrease of tendon strings in both age groups. In infants less than one string pulled out from one mastoid muscle (Fig. 2), the maximum number of them reached 9. In infants it reached the maximum number of 12.

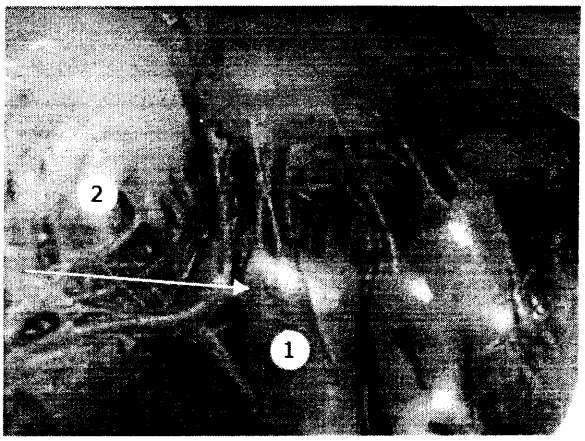

Figure 1. Tendon string valvular heart baby infants. 1 - mastoid muscle, 2 - tendon strings.

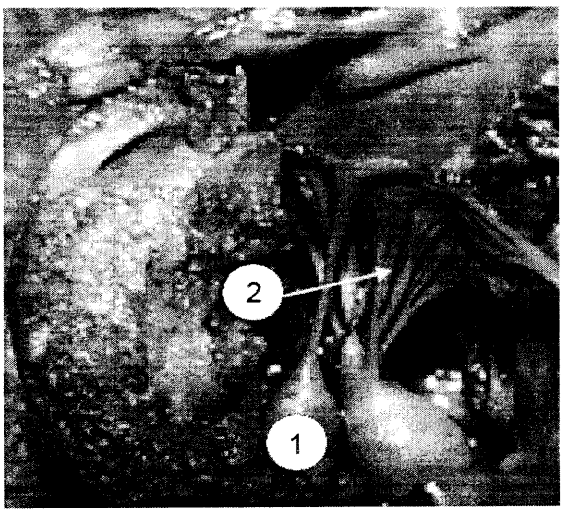

Figure 2. Tendon string valvular heart newborn baby. 1 - mastoid muscle, 2 - tendon strings.

Tendon strings on each mastoid muscle were connected mostly to the appropriate valve and to a lesser extent to the neighbors. Number of tendon strings was greater in boys than girls in both atrial ventricular valves in both age groups.
Morphological features, typical of tendon strings as newborns and infants is the formation of beams in connection with a shutter valve.
On his way to the wings they diverse to string first, second and third order placer or dichotomous way. Moreover, with each division the diameter tendon strings decreases. Therefore wings atrioventricular valvular children attached tendon is much more strings than away from mastoid muscle.
According to light microscopy tendon strings of newborns and infants under morphological classification according to the literature were divided into fibrous and fibro-muscular. In the fibrous tendon strings type the entire volume of the strings was dense connective tissue, such as parallel bundles of collagen fibers, between which are placed a number of highly differentiated fibroblastic cells. Outside a tendon string was covered with a layer of endothelium (Fig. 3).

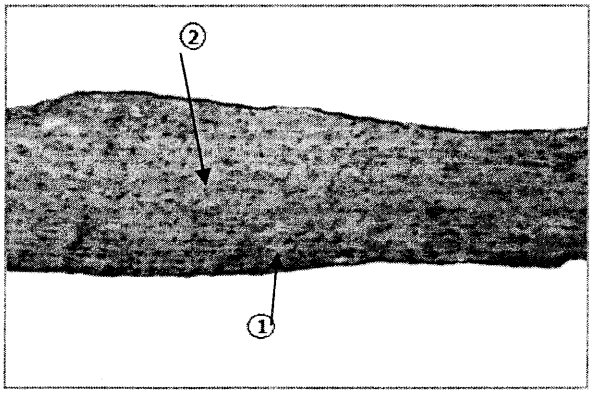

Figure 3. Longitudinal section of fibrous tendon strings mitral baby infants. Coloring hematoxylin-eosin. x150.
1 - endothelium 2- collagen fibers.

String tendon fibro-muscular type consisted of connective tissue components and individual cardiomyocytes, which were located in the spaces between bundles of collagen fibers (Fig. 4). Also, some tendon strings when stained with hematoxylin-eosin were observed more "light areas" that meet the localization of cardiac muscle cells. These cells per histological structure were similar with top cardiomyocytes. These cells are classified in the literature as "Purkinje-like." They occurred more often in places discharge tendon strings from the top mastoid muscle with a tendency to decrease toward the leaf valve and their number decreased with the age of the child.

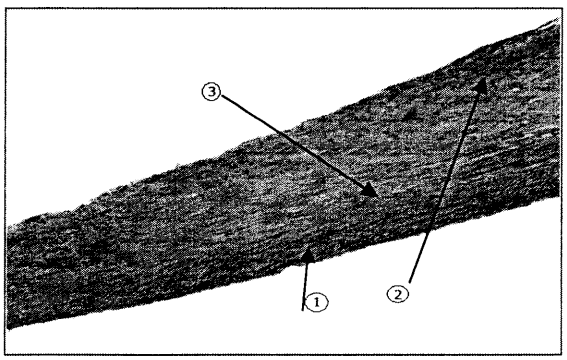

Figure 4. Longitudinal section of fibro -muscular tendon strings mitral valve newborn baby. Coloring hematoxylin - eosin. x150. 1 – endothelium; 2 - collagen fibers; 3 - cardiac muscle cells.

It would be advisable to study the Stokes vector of parameters of laser images of histological sections of tendon strings atrio-ventricular valves given the development of a new direction - laser polarimetry biological tissues[3-8], which aims to study the characteristics of image structure.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Material studies provided three-sided and mitral valve that were taken from 8 hearts of stillborn children and four dead infants. The resulting material was fixed in 10% neutral formalin solution with thrice change retainer described macroscopically. Putting in alcohol increasing concentration, after which the material was put in paraffin and made serial histological sections 10 microns thick were stained with hematoxylin and eosin by standard methods. In the study used the method of macroscopic , histological slides method to the study by light microscopy. Polarization image tendon tissue valvular heart strings was received via object glass that projected into the plane of the light-sensitive area (800x600 pixels) CCD camera, which provides a measuring range of structural elements of biological tissues for the following sizes: 2 mm - 2000 mm. To evaluate the diagnostic capabilities of statistical image analysis of tissue valvular heart studied not painted histological sections (30 drugs).

Analytical approach[9-12] to the analysis of polarizationally inhomogeneous images of human prostate tissue is based on the main model theses of laser polarimetry technique, according to which biological tissue (BT) is treated as a monolayer containing the ensemble of optically uniaxial birefringent fibrils.

This work is directed to the investigation of the scope of the technique of laser polarimetry and polarization spectrometry of oncological changes of the human prostate tissue under the conditions of multiple scattering, which presents a more general and real experimental clinical situation.

Statistic moments of the first (M), second (σ), third (A) and fourth (E) orders were used as the analytical tool for estimating the ensemble of random values of z, that characterize the image of biological object (intensity I, polarization azimuths α and ellipticities β) and its optical-geometrical structure (orientation directions of the protein fibrils and birefringence index of their substance Δn).

It has been mentioned that appearance of pathogen processes is accompanied by biochemical degradation of optically anisotropic protein structures and disorientation of fibrils of their architectonic net. Such transformations of BT structure can be connected with the increase of orientation dispersion of the protein fibrils ensemble: pathological growth of protein fibers and formation of prevailing, spatially localized directions of their growth are observed.

Optical scheme of investigation of polarization images of tendon strings tissue is presented in Fig. 5. The illumination was performed by parallel bundle of He-Ne laser. Polarization illuminator consists of quarter-wave plates 3; 5 and polarizer 4, that provides the formation of a laser bundle with random azimuth or ellipticity of polarization.

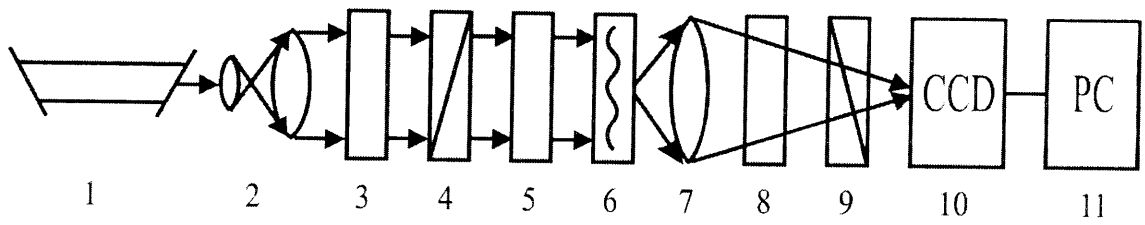

Figure 5. Optical scheme of investigation of statistical and fractal structure of polarization images of histological sections of the tendon strings tissue.

Polarization images of BT were projected by means of microobjective 7 onto the plane of light-sensitive plate (800x600 pixels) of CCD-camera 10, which provided the range of measurement of structural elements of BT for the following sizes (2 μm – 2000 μm).

For estimation of diagnostic potentialities of statistical analysis of the prostate tissue images the histological sections of physiologically normal (21 samples) and changed (22 samples) of the tissue were investigated.

Polarization images of optically thin (reduction factor $\tau \leq 0{,}1$, geometrical thickness 40 μm) histological sections of healthy tendon strings obtained for coaxial (0-0) and crossed (0-90) polarizer 4 and analyzer 9 are presented in Figure 6-7.

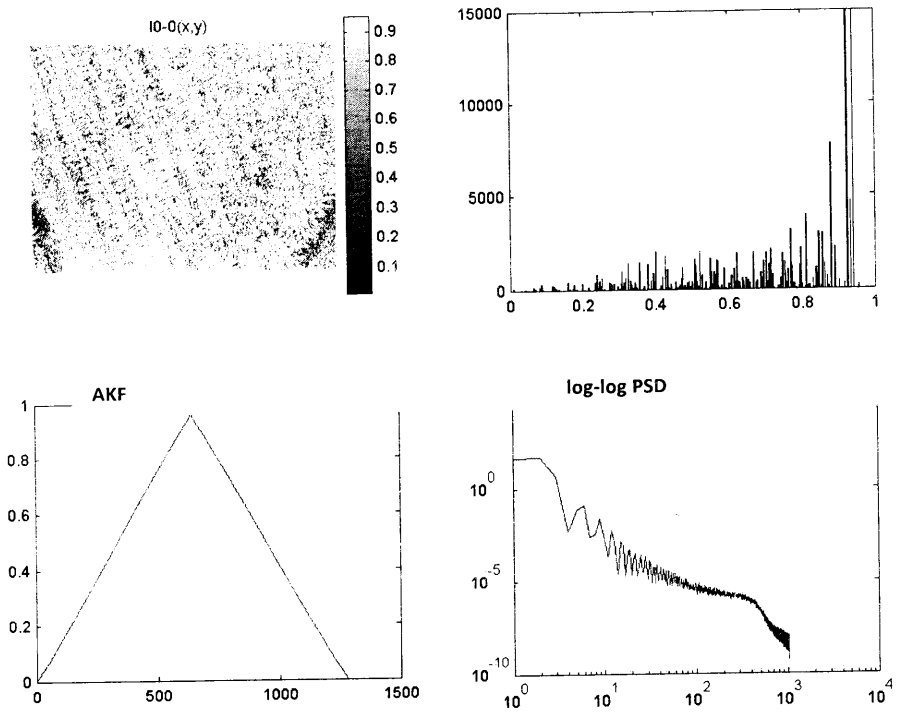

Figure 6. Polarization images of optically thin layers of tendon strings tissue obtained for coaxial (0-0) polarizer and analyzer

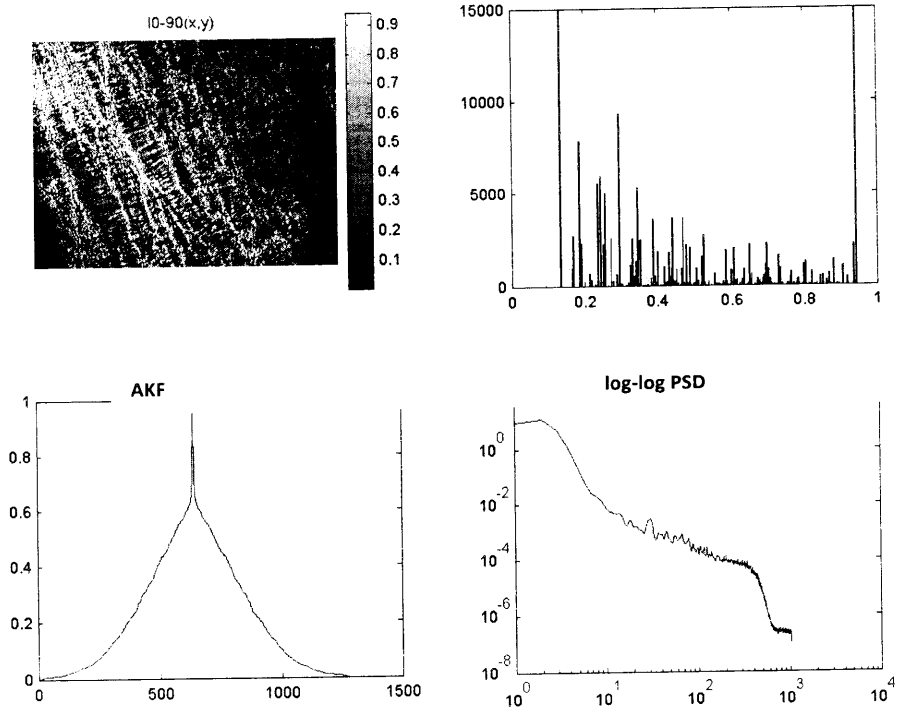

Figure 7. Polarization images of optically thin layers of tendon strings tissue obtained for crossed (0-90) polarizer and analyzer

Table 1 presents the values of statistic moments of the 1st-4th orders of intensity distributions of polarization images of the tendon strings tissue. The analysis of the obtained results proved the high diagnostic sensitivity of statistic moments of the 3rd and 4th orders of intensity distributions of matrix elements of the BT of both types to the change of their optical-geometrical structure.

Table 1. Statistic moments of the 1st-4th orders of intensity distributions of polarization images of the tendon strings tissue.

I	$I(0-0)$		$I(0-90)$	
M_i	tendon strings newborns	tendon strings newborns	tendon strings infants	tendon strings infants
M	0,9 ± 5%	0,61 ± 6%	0,6 ± 4%	0,63 ± 5%
σ	0,23 ± 4%	0,3 ± 5%	0,29 ± 6%	0,20 ± 8%
A	38,6 ± 7%	82,9 ± 9%	26,8 ± 11%	64,3 ± 14%
E	74,2 ± 9%	136,1 ± 12%	132,8 ± 14%	261,2 ± 18%

The analysis of the obtained results showed high diagnostic sensitivity of statistic moments of the 3rd and 4th orders of coordinate distributions of matrix elements of both types of BT to the changes of optical-geometric structure.
Figure 8 presents the ensemble of log-log dependencies of intensity distributions of polarization images of physiologically normal (upper row) and pathologically changed (lower row) tendon strings tissue.

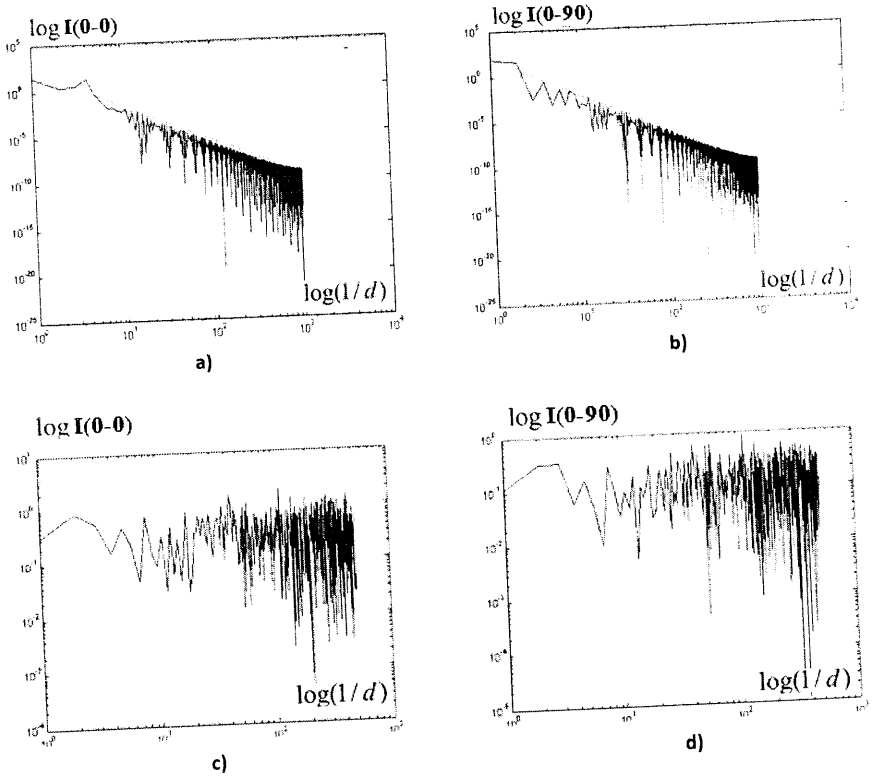

Figure 8. Power spectra (log-log dependencies) obtained for intensity distributions of the tendon strings tissue polarization images with statistical structure of architectonic net

The results of fractal and statistic processing of experimentally obtained intensities distributions $I(0-0)$, $I(0-90)$ of the samples of healthy and changed human tendon strings tissue are illustrated in Figures 7 and 8. Fractal analysis of coordinate of the intensity distributions of polarization images of the prostate tissue samples of both types proved their being statistic.

The third statistic moment (A) proved to be the most sensitive to pathological changes in orientation structure. Its value in the intensity distribution of polarization image $I_{(0-90)}$ of changed tissue is 3 times higher if compared with the similar statistic parameter of the intensity distribution of the healthy tissue.

CONCLUSIONS

The following conclusions are made on the results of the investigation:

- Morphological analysis of atrioventricular valvular of newborns and infants showed that the number of tendon strings atrioventricular heart valves, which depart from the mastoid muscle and attached to the valve cusps can vary from 30 to 80. In tendon strings fibro- muscular type in the spaces between bundles of collagen fibers developed heart muscle cells are often detected in newborns;
- Analysis of the obtained results showed high diagnostic sensitivity of statistic moments of coordinate distributions of matrix elements of both types of chordae tendianeae of atrioventricular valves hearts tissue to the changes of optical-geometric structure.

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