DEVELOPMENT OF LASER-OPTICAL METHODS FOR MONITORING THE BIOMECHANICAL PROPERTIES OF THE ANTERIOR PART OF THE EYE

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Glaucoma and keratoconus are diseases caused or accompanied by violations of the biomechanical characteristics of eye tissues, in particular with a weakening of the strength properties of the cornea, and are a typical undesirable consequence of modern keratorefractive surgery. Timely detection of a decrease in corneal strength would allow diagnosing the problem at an early stage and significantly reduce the risk of iatrogenic pathology. The risk of developing glaucoma and keratoconus of the eye is associated with pathological changes in the biomechanical properties of eye tissues such as the cornea and sclera. Thus, the problem arises of studying tissue biomechanics and the possibility of influencing it. For this purpose, experiments were carried out to determine the dynamics of elastic properties of intact and modified tissue of the sclera and cornea of the pig's eye by OCT elastography and speckle interferometry.

Purpose of work: To study the correlations between the mechanical properties of eye tissues under laser exposure from IOP using OCT elastography and speckle interferometry.

RESULTS

OCT elastography of eye tissue
The OCT setup was created in Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia by a group led by Vladimir Y. Zaitsev.

For the cornea, irradiation was carried out along the central line of the cornea with a pulse-periodic mode; a total of 5 irradiation peaks were obtained when analyzing the OCT graph. The dependence of the behavior of the amplitude of deformations on the value of IOP was revealed.

For the sclera, irradiation was carried out in the Pars plana region with a pulse-periodic mode, the total duration of irradiation was 2 sec (a total of 5 irradiation peaks were obtained).

The analysis showed that for normal pressure (16 mmHg) the clearest picture of tissue response to a laser pulse is observed - a clear increase in stresses with their rapid and complete relaxation after the completion of irradiation. Whereas for IOP above or below the norm, there is an indistinct tissue response to laser exposure and not complete relaxation of internal stresses.

Speckle interferometry of eye tissue
We used a LS-1.56 fiber laser (IPG Photonics Corp.) operating at a wavelength of 1.56 μm, with an output power of up to 5 W. Irradiation mode: pulse-periodic mode, power density 15-56W/cm², exposure time 15 s. The probe beam, reflected normally to the sample, is detected by a 2D camera (21 frames/s) to obtain an image and to monitor changes in the statistical properties of speckle patterns caused by heating.

In the comparative graphs above, presenting the dependence of the contrast function and the correlation on time for the pulse-periodic mode, the motion of tissue inhomogeneities is noted, associated with its periodic thermal expansion and contraction due to the laser operation mode.

For central and peripheral areas of the cornea
The oscillation amplitude of the contrast function for a central part of the cornea is noticeably smaller compared to the oscillation amplitude for the periphery, which indicates a higher thermal resistance for central points.

Temporal dependences of contrast and temperature during initial and repeated pulse-periodic heating of the cornea
The biological tissue was irradiated for 20 seconds, then it was soaked in saline for 5 minutes, and a 20-second irradiation was repeated. The obtained graphs showed a qualitative similarity in the rate of decrease in the contrast function and the similarity of temperature profiles. The maximum achieved temperature also coincides, which allows us to conclude that the thermomechanical characteristics of the cornea are restored. The scatter of the results of repeated experiments lies within 10% while maintaining the qualitative shape of the curves, which indicates the potential use of this method as a control system.

Anknowlegments
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