Are biomechanical properties of the sclera and eye hydrodynamics related? An experimental study

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It is hypothesized that impaired biomechanical properties of the sclera around the optic disc and, largely, in the corneoscleral shell may play an essential role in the pathogenesis of primary open-angle glaucoma (POAG). The paper’s objective is to experimentally investigate the impact of elastic scleral properties on intraocular fluid (IF) outflow.

Material and methods: We determined the mechanical characteristics and the crosslinking level of the sclera as well as hydrodynamic parameters in three groups of experimental animals: 1) intact eyes of young (2 months of age) and old (2 years) rabbits; 2) eyes treated in vivo by threose, which increases crosslinking of scleral collagen; 3a) eyes of young and old rabbits after they were treated by collalysin, a proteolytic enzyme, 3b) eyes of rabbits pre-treated by treose and subsequently treated by collalysin. The hydrodynamic parameters were measured using Glautest 60 (Russia). To determine the crosslinking level of scleral collagen, we used differential scanning calorimetry and measured denaturation temperature (Td), whose rise points to an increased degree of collagen crosslinking. The biomechanical parameters of the sclera were determined by Autograph AGS-H (SHIMADZU, Japan).

Results: The normal age-related increase of scleral stiffness (Young’s modulus) from 23.1 ± 4.2 MPa to 41.4 ± 6.3 MPa (p < 0.05) was shown to go together with a moderate growth of cross links (Td) from 67.7 ± 1.1°C to 69.5 ± 1.3°C (p > 0.5) and a somewhat reduced IF outflow. At the same time, an increase of scleral stiffness (to 65.4 ± 6.0 MPa) caused by threose, i.e. a pathological growth of crosslinking (Td = 76.6 ± 1.6°C, p < 0.05), is accompanied by a certain IOP increase and a significant impairment of IF outflow: from 0.20 ± 0.02 to 0.12 ± 0.01 mm³/min/mmHg (p < 0.05). Collalysin-treated old rabbits revealed a fall in scleral stiffness (to 27.9 ± 4.9 MPa) and an improved IF hydrodynamics, whereas young animals showed only a slight change in these parameters. The sclera treated by threose and containing excessive cross links also became less stiff (43.4 ± 4.5 MPa) and improved IF hydrodynamics (0.21 ± 0.03 mm³/min/mmHg) after collalysin treatment. It may be assumed that the biomechanical properties of the sclera have an effect on eye hydrodynamics.

Conclusions: Indeed, IF outflow is deteriorating with the increase of scleral stiffness that is due to excessively generated cross links in its collagen structures, which may be a risk factor for POAG. Proteolytic therapy with collalysin helps reduce the amount of these links, make the sclera less stiff and improve hydrodynamic parameters of the eye.