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Dynamics of Trabecular Meshwork Deformation under Pulsatile Intraocular Pressure

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Abstract: Elevated intraocular pressure (IOP) is the most important risk factor for disease progression in glaucoma patients. The elevation is predominantly due to the increase in the aqueous outflow resistance in the trabecular outflow pathway. Recent data have shown that the resistance increase is correlated with changes in the tissue stiffness. To this end, we developed a mathematical model to simulate how the tissue stiffness can affect the deformation of the trabecular meshwork (TM) that can be determined experimentally. The goal of the study is to develop a method to non-invasively determine the TM stiffness in patients through measurement of the TM deformation.

The outflow pathway structurally consists of the TM, the endothelial lining of the Schlemm's canal (SC), the collecting channels (CCs), and the episcleral veins. The TM contains tissue three layers: uveal meshwork, corneoscleral meshwork, and juxtacanalicular tissue (JCT) [1]. The human SC can be considered as a circular channel around the TM; and is connected to the episcleral veins via ~30 CCs [2]. Based on our previous studies [3-4], a three-dimensional model was developed to simulate the TM deformation. To simplify the geometry, the uveal and corneoscleral meshworks were combined into a single layer (UCM), and JCT and the inner wall of the SC into the JIW layer. The model geometry was assumed to be rotationally symmetric, in which the stress and the deformation are the same for every 12^o rotation around the optical axis. There was one CC in each 12^o segment, and two adjacent segments were included in the current simulation. All tissues except the UCM in the model were assumed to be isotropic, incompressible, and linear elastic materials. The UCM was treated as a transversely isotropic (TI) material with its axis of symmetry being in the circumferential direction [4].

The simulations were performed using the finite element method implemented in a commercial software ABAQUS. We first simulated changes in the SC cross-sectional area induced by the elevated fluid pressure in SC. The pressure was elevated gradually from 10 mmHg to 50 mmHg [5]. The simulation results were compared with the experimental data in the literature [5], to determine the materials properties of the TM tissue. Additionally, we analyzed the dynamics of the TM deformation under the physiological oscillation of the IOP. The results from the simulations provided a theoretical framework for future studies to determine the TM stiffness in normal and glaucoma patients based on optical measurements of the TM deformation.

Keywords: Trabecular meshwork; schlemm's canal; transversely isotropic; deformation

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