Patient oriented modelling of heat and fluid flow in ocular cavities and porous tissues

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ABSTRACT

Surgical techniques involved in treatment of glaucoma for human eye is a major concern among the medical researchers. The mathematical modelling of Aqueous Humour (AH) flow in Anterior Chamber (AC) along with ocular drainage device assist in optimizing the design of these devices to solve the issues like deregulated AH outflow and excess IntraOcular Pressure (IOP). A patient oriented numerical procedure has been implemented in this study along with eye model to assess the influence of conventional surgical technique, trabeculectomy, and the implantation of surgical devices like iStent inject [1] and the novel Silicon Shunt Device (SSD) with respect to flow field parameters.

The 2D eye model extracted from the tomographic image of eye based on segmentation technique forming the computational domain is subjected to numerical analysis by means of the finite volume solver OpenFOAM. The Trabecular Meshwork (TM), Schlemm's Canal (SC) and ocular devices are modelled in the current eye model. The solver is customized to incorporate the generalized porous medium model [2, 3] to solve heat and fluid flow inside the free fluid domain (AC) and the porous domain (TM). The numerical procedures starting from extraction of computational domain to post processing are performed in open source tools.

The present model has allowed to correlate IOP and permeability of TM for healthy and glaucomatous eye conditions. Conventional glaucoma surgical technique trabeculectomy allows a decrease of IOP from 22.8 mm Hg to 10.5 mm Hg. Independent 3D numerical analysis performed on iStent inject and SSD showed that iStent offers more flow resistance to AH flow compared to SSD. The higher flow resistance in iStent is due to non-uniform configuration comprising central lumen and side lumens of small diameter. Glaucoma drainage devices incorporated in the current eye model, iStent inject and SSD, allow a decrease of IOP from 22.8 mm Hg to 10.7 mm Hg and to 8.5 mm Hg in SSD, respectively.

The present patient-oriented numerical procedure, involving the use of the generalized porous medium model, can be a useful tool for ophthalmologists to analyse the effects of different surgical techniques on IOP.

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