Modeling of Drug Distribution in the Human Vitreous

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Abstract : The injection of a drug into the vitreous body for the treatment of retinal diseases like wet aged-related macular degeneration (AMD) is the most common medical intervention worldwide. We develop mathematical models for drug transport in the vitreous body of a human eye to analyse the impact of different rheological models of the vitreous on drug distribution. In addition to the convection diffusion equation characterizing the drug spreading, we use porous media modeling for the healthy vitreous with a dense collagen network and include the steady permeating flow of the aqueous humor described by Darcy's law driven by a pressure drop. Additionally, the vitreous body in a healthy human eye behaves like a viscoelastic gel through the collagen fibers suspended in the network of hyaluronic acid and acts as a drug depot for the treatment of retinal diseases. In a completely liquefied vitreous, we couple the drug diffusion with the classical Navier-Stokes flow equations. We prove the global existence and uniqueness of the weak solution of the developed initial-boundary value problem describing the drug distribution in the healthy vitreous considering the permeating aqueous humor flow in the realistic three-dimensional setting. In particular, for the drug diffusion equation, results from the literature are extended from homogeneous Dirichlet boundary conditions to our mixed boundary conditions that describe the eye with the Galerkin's method using Cauchy-Schwarz inequality and trace theorem. Because there is only a small effective drug concentration range and higher concentrations may be toxic, the ability to model the drug transport could improve the therapy by considering patient individual differences and give a better understanding of the physiological and pathological processes in the vitreous.

Keywords : coupled PDE systems, drug diffusion, mixed boundary conditions, vitreous body
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