Mathematical models of fluid flow in the vitreous chamber of the eye

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Abstract

The vitreous cavity is the largest chamber of the eye, it is delimited anteriorly by the lens and posteriorly by the retina and it is filled by the vitreous humour. In young subjects the vitreous is a viscoelastic fluid and has the consistency of a gel; however, with advancing age, it typically undergoes a liquefaction process, leading to the progressive collapse of the collagenous framework of the gel. The vitreous has the important mechanical functions of supporting the sensory layer of the retina in contact with the pigment epithelium and acting as a diffusion barrier between the anterior and the posterior segments of the eye.

Understanding the dynamics of the vitreous humour induced by eye rotations is relevant for the following two main reasons. i) Several indications exist that the occurrence of retinal detachment is closely related with the stress that the vitreous exerts on the retina. ii) An effective way of delivering drugs to the retina is by direct intravitreal injection; the efficiency of the procedure and the level of drug concentration on the retina depend on drug transport processes within the vitreous. When the vitreous moves advective transport may play a dominant role.

In the first part of the talk various models of vitreous dynamics induced by eye rotations will be presented and discussed, with particular focus on the stresses exerted by the vitreous on the retina. Both the physiological case and various pathological states will be considered, in particular myopia and vitreoschisis (a split in the vitreous cortex, the outermost part of the vitreous).

In the second part of the talk age macular degeneration (AMD) will be considered. This is a major retinal disease, related to damage of the macular region of the retina. There is a growing evidence that AMD development is related to fluid accumulation in the sub-retinal space, which occurs partly due to retinal pigment epithelium (RPE) pumping failure. Water flow across the RPE is arguably mainly driven by osmosis and electro-osmosis. A mathematical model that couples electrophysiology and fluid dynamics in the RPE will be presented, aimed at providing a mechanistic understanding of water transport across the RPE. This could be of great utility for ophthalmologists, particularly for the choice of drugs to treat AMD.