Multi-physics simulations of the human eye

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ABSTRACT

The mathematical modelling of the human eye naturally shows fluid-fluid and fluid-structure interactions. Different biological tissues interact with each other and each of them shows a different mechanical behavior. In the eye we find compartments such as the sclera that are usually modelled as elastic shells, while others, such as the capillaries bed present in the eye could be model as flow in porous media.

In such a complex system we have mainly worked on two different phenomena. The first one is the blood flow in the retinal arterioles [1]. In those arterioles fluid-structure interaction is important, since the smooth muscle cells (SMCs) present on the vessel wall are responsible for the regulation of the flow [2]. In order to perform FSI simulations on a network of retinal vessels coming from fundus images we have devised a simplified model of the structure. The vessel wall is described via a non-linear Koiter shell model embedded as a boundary condition in the fluid problem and active fibers model the presence of SMCs.

The second phenomenon we have been studying concerns the description of the eye as a multi-domain and multi-physic system. We are interested in reproducing and understanding the different mechanisms that concur to build the Intra Ocular Pressure (IOP). In particular, it has been observed that the IOP, measured at the level of the cornea, is pulsatile [3]. The reason of this pulsations is probably due to the pulsatile blood flow passing through the choroid. This tissue, located between the retina and the sclera, contains capillaries that bring nutrients to the back of the retina. In the proposed model of the eye the choroid is described as poro-elastic medium that interacts with other compartments such as the sclera, the vitreous or the anterior chamber. A coupling between all these compartments can allow us to identify the main mechanisms explaining the IOP and to link its variation with the eye hemodynamics.

REFERENCES

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