Contribution ID: **185** Type: **Oral 20 Minutes**

Mixed-dimensional models of the brain's waterscape with FEniCS

Wednesday, 16 May 2018 14:55 (15 minutes)

The clearance of the metabolic waste in the body is handled by the lymphatic system. Except in the brain, which appears to be the only organ devoid of lymphatic channels. Indeed, the mechanisms underlying the clearance processes of the brain are still unknown, and the topic sparks debate and controversy. What is clear however, is that dysfunction of cerebral metabolic waste clearance is associated with neurodegenerative disorders such as Alzheimer's disease.

The term the brain's waterscape refers to the circulation, flow and exchange of tissue fluid and transport of solutes through the brain. While these processes are not fully understood yet, most hypotheses point out the major role of the cerebral blood vessels and possibly paravascular spaces. We propose to investigate these processes using a mathematical approach based on coupled mixed-dimensional models mimicking the vasculature and paravasculature as topologically one-dimensional structures embedded in a three-dimensional porous medium.

This talk introduces a mixed-dimensional model dedicated to the interaction between the brain tissue, the vasculature and the paravasculature, aiming at gaining new insight into the waste clearance process of the brain. The development of this model relies on the FEniCS open-source finite element library [1]. We will also present dedicated features developed in a wider context of automating mixed-dimensional finite element in FEniCS. The introduced tools will be illustrated by concrete examples of applications in biomedicine in general and for the brain's waterscape in particular.

References

[1] M. Alnæs, et al. The FEniCS Project Version 1.5. Archive of Numerical Software 3.100 (2015): 9-23. www.fenicsproject.org

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Session Classification: Parallel 8-B

Track Classification: MS 2.25: Hierarchical Flow Modelling in Biological Systems