COUPLING AGENT BASED METHOD AND COMPUTATIONAL FLUID DYNAMICS FOR PLAQUE DEVELOPMENT IN THE CAROTID ARTERY

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1. Introduction

Atherosclerosis is a progressive disease characterized in particular by the accumulation of lipids and fibrous elements in artery walls [1]. It is characterized by dysfunction of endothelium, vasculitis and accumulation of lipid, cholesterol and cell elements inside blood vessel wall. This process develops in arterial walls with discrete nature between cells, molecular biomarkers, which indicate that discrete modelling approach like Agent Based Model (ABM) can be used for simulation of complex process for plaque development. We here concentrate for carotid artery plaque development.

2. Materials and Methods

Beside agents, the agent-based simulations require a domain where the agents will live and exhibit their behavior. Deep learning technique was implemented for segmentation from Ultrasound images. The automatic carotid artery (lumen and wall) segmentation has been done using SegNet and U-Net based deep convolutional networks.

The initial geometry for ABM was a 2D circular cross-section composed by 3 concentric layers - tunica intima, media and adventitia with the internal and external elastic laminae - IEL and EEL.

3. Results

Blood flow through a curve blood vessel with stenosis was modeled using 3D finite element method (FEM). Fluid dynamics computation is performed by PAK solver, giving velocity and pressure field, as well as wall shear stress distribution [2]. ABM method was applied on the arterial wall taken into account cell mitosis and ECM production in the intima including lipid cells.

Figure 1: Curved artery example with coupled ABM and CFD

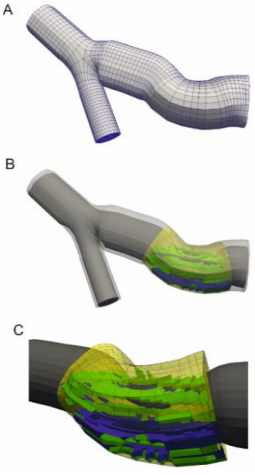

Figure 2: Carotid artery example with coupled ABM and CFD finite element. **A** – Full model, **B** - Transparent model with colored plaque components, **C** – Augmented part with the FE elements defined as plaque

Curved and carotid artery example with coupled ABM and CFD finite element has been presented in Figs. 1 and 2.

4. Discussion and Conclusions

Specific carotid artery patient from US was modeled with coupled FEM and ABM method. First results show good agreement between proposed method and clinical measurements in the follow up 3D US image reconstruction.

5. References

1. Libby P Inflammation in atherosclerosis. Nature 420:868–874. (2002)
2. Filipovic ND, Zivic M, Obradovic M, Djukic T, Markovic ZS, Rosic M, Numerical and experimental LDL transport through arterial wall, Microfluidics and nanofluidics, Vol.16, No.3, pp 455-464, ISSN 1613-4982, (2014).

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