# Implementation of growth and remodeling model in 3D finite element code: application to abdominal aortic aneurysm

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**ABSTRACT**

Constrained mixture growth and remodeling model [1] are widely used for modeling adaptation of vascular tissue. They have been implemented into 1D semi-analytical solutions, and they have been implemented using membrane finite elements (e.g., [2]) to model problems that cannot be approximated by geometries for which there are known semi-analytical solutions. One of these problems is abdominal aortic aneurysm. However, the aorta is a thick walled structure, and therefore membrane models cannot capture completely all the aortic features. Additionally, vascular growth is strongly dependent on the distribution of stresses throughout the wall, which is not described by membrane stress. Therefore, there is a pressing need to implement constrained mixture models into 3D finite elements. The first attempt to do so was presented in [3].

In this study we present the implementation into the finite element analysis program (FEAP) and its application to modeling growth of abdominal aortic aneurysms from healthy aorta to the final outcome (rupture, stabilization or continuation of growth). Implementation of the model entailed several challenges. Incompressibility of material was enforced by using penalty functions and the Augmented Lagrange method. While the first attempt of using full 3D finite elements for describing growth of aneurysms [3] used deviatoric split for describing strain energy functions of fibers (i.e., collagen and smooth muscle cells), we used a mixed formulation, as was suggested in several investigations, e.g., [4]. This formulation proved to be more stable, and obtained results for adaptation of the aorta to changes in hemodynamics that correlate with semi-analytical solutions.

To model aneurysms, elastin was degraded unevenly spatially, similarly to [5]. A parametric study was conducted to investigate influence of certain collagen turnover parameters, and the results were compared to results from membrane models [5].

Acknowledgement

This work has been fully supported by Croatian Science Foundation under the project IP-2014-09-7382.

## References

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