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Monitoring of the behaviour of intracranial aneurysms with OpenFOAM

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Understanding physiological processes is key to treat patients, especially in emergency situations. For this reason, the understanding of the behaviour of aneurysms in the human brain has been the study of research for decades. With a better understanding of the processes involved the treatment of patients can be improved.

To computationally model the processes involved, it is of utmost important to correctly describe the behaviour of both the fluid (blood) as well as the blood vessel. For this a Fluid-Structure Interaction (FSI) toolkit is required which can correctly describe the fluid dynamic side as well as the solid mechanic side (including non-linear behaviour). The solids4Foam user developed library [1] is well suited for this purpose.

In previous works [2,3,4,5] the basis for the workflow from angiogram data, over meshing, simulation and post-processing was established. Thus, more complex statistical analyses are possible to gain knowledge in the area of aneurysm growth as well as rupture. Additionally, it is possible to track the behaviour of the aneurysm of a patient and clearly identify problematic developments.

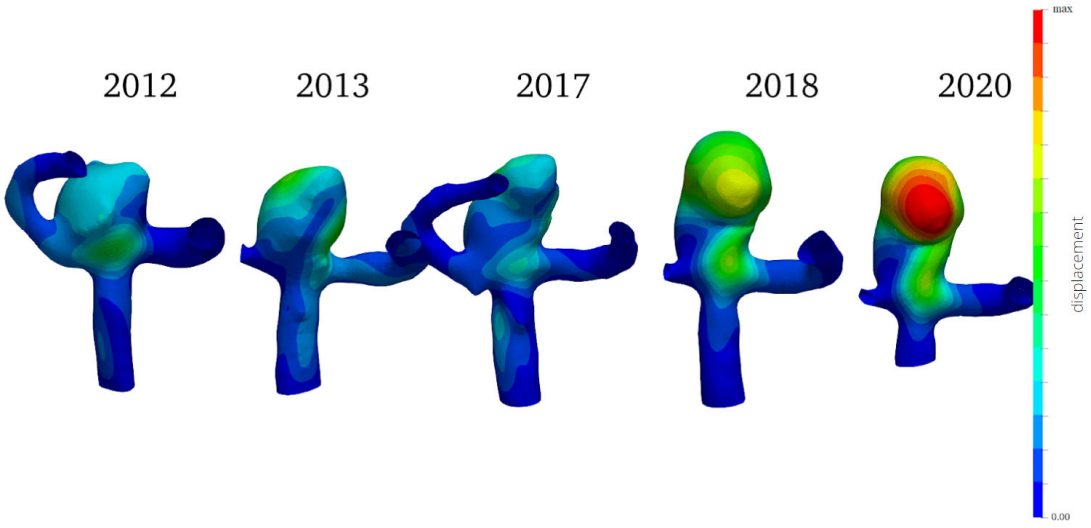

Figure: Simulation results of displacement in an aneurysm in different growth stages over 8 years

In this work a patient's anonymized aneurysm geometry over a period of 8 years is investigated in five simulations (see figure above). Most important quantities as well as characteristic numbers are compared over the time period in order to learn about the behaviour of a ruptured aneurysm.

With the developed models and workflow in future a vast variety of aneurysms can be investigated to understand existing aneurysms as well as the possible onset and rupture of aneurysms.

References

[1] P. Cardiff, A. Karač, P. De Jaeger, H. Jasak , J. Nagy, A. Ivanković and Ž. Tuković: An open-source finite volume toolbox for solid mechanics and fluid-solid interaction simulations, arXiv:1808.10736v2, 2018, available at https://arxiv.org/abs/1808.10736

[2] J. Nagy, P. Cardiff: Numeric investigation of Fluid-Structure Interaction for internal flow processes, 7th OpenFOAM conference 2019, Berlin, Germany

[3] J. Nagy, P. Cardiff, V. Miron, Z. Major: Modeling hyperelastic solids in OpenFOAM, 8th OpenFOAM conference 2020, Berlin, Germany

[4] J. Nagy, V. Miron, Z. Major, P. Cardiff: Fluid-Structure Interaction simulations in OpenFOAM with hyperelastic models for aneurysm modelling, 16th OpenFOAM Workshop, Dublin, Irland, June 2021

[5] J. Nagy, V. Miron, Z. Major, P. Cardiff: Analysis of the behaviour of intracranial aneurysms with OpenFOAM, 9th OpenFOAM Conference, online, October 2021