Simulating Blood Flow
M.Sc. project

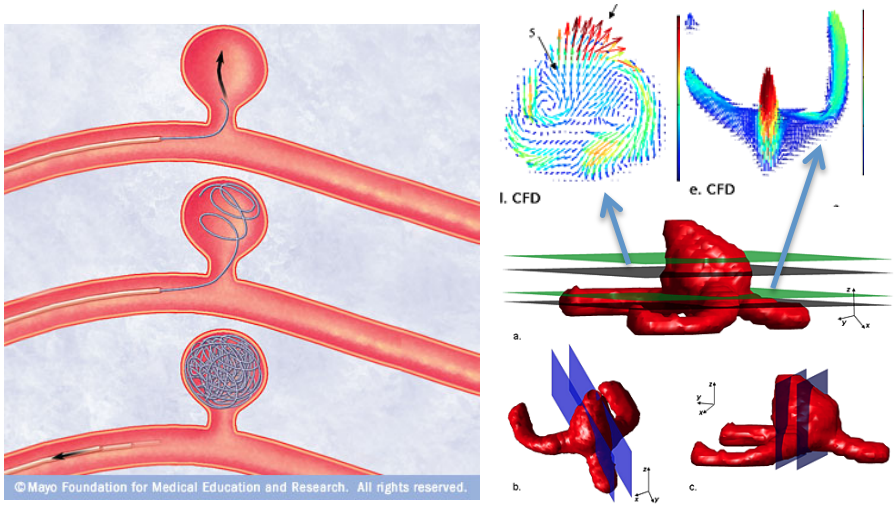
This project is intended for M.Sc. students of 3ME, Applied Physics or Aerospace Engineering; The work will be carried at the Laboratory for Aero & Hydrodynamics, part of the Process & Energy department (www.pe.tudelft.nl) of the Faculty of Mechanical, Maritime and Materials Engineering.

Blood flow plays a critical role in the development of aneurysms – "balloon"-like structures that occur as a result of a local weakening of the blood vessel wall. The forces due to blood flow can make aneurysms grow and (potentially) make them rupture. Currently, knowledge of the eventual fate of an aneurysm is lacking: sometimes an aneurysm will stay "stable" for the rest of a patient's life, while other may rapidly increase in size and rupture, which is a life-threatening event. Treatment of aneurysms is done using clipping (blocking flow from the vessel into the aneurysm) or by filling it with a long coil (reducing the flow inside the aneurysm). Both lead to blood clotting, which effectively fills up the structure, so that it is stabilized.

In this project, you will use OpenFOAM, an open source code for simulating flow problems, to address the complex flows in aneurysms. The code is currently running and has been shown to work in blood vessel-like structures. You will use this code, adapting it where necessary, to address one of the following questions:

- How is the flow inside an aneurysm affected by placing a long coil? How can we effectively model this coil?
- The flow inside an aneurysm is in an intermediate Reynolds regime, but highly pulsatile. This creates very complex flow patterns. How can we extract relevant information about this flow from a simulation (e.g. wall shear stress)?
- As the walls are weakened, the pulsatile effects of the flow will probably have a strong effect on the flexible walls. Can we incorporate flexible walls in the simulations, and how do these affect the flow compared to "stiff" walls?
- Blood is a complex, non-Newtonian fluid. Is the rheology of blood important, or can we model flows with a simple Newtonian model?

Obviously, these four questions are just general indications; other goals can be formulated. This project focuses on simulations and some programming experience and knowledge of linux is highly desirable. The work will be done in close collaboration with colleagues at the Amsterdam Medical Centre (Biomedical Engineering and Physics, Radiology).



Left: Coiling of an aneurysm [Mayo Clinic]; Right: geometry and flow simulation results of an aneurysm obtained from an angiogram of a patient [Van Ooij et al., NMR in Biomedicine 2012].

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