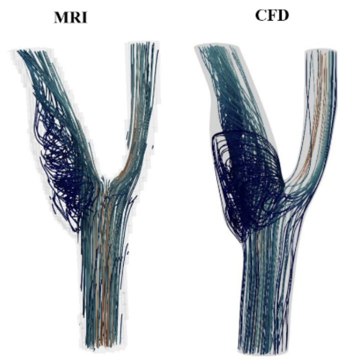
Master thesis proposal

Numerical study of hemodynamics in a stenosed patient-specific carotid bifurcation

Abstract

Internal carotid artery (ICA) stenoses represent a threat as they can lead to brain stroke. Besides cardiovascular risk factors (e.g., high blood pressure, high cholesterol, smoking, etc.), plaque composition and carotid bifurcation geometry, hemodynamic wall parameters (e.g., wall shear stress) represent additional risks for the progression and rupture of ICA atheroma. Time-resolved and three-dimensional flow magnetic resonance (4D flow MRI) allows measuring blood flow, however, only at limited spatial and temporal resolution. The lack of resolution hampers detailed and accurate quantification of blood flow parameters. Computational fluid dynamics (CFD) is a powerful tool for studying hemodynamic parameters in blood flow. When combined with 4D flow MRI, it can provide even more detailed and accurate results, particularly for studying complex flow patterns in cardiovascular diseases.

The goal of this master thesis is, by means of computational simulations (using OpenFOAM, https://www.openfoam.com/), to investigate the effect of inlet velocity profiles and test different approaches (laminar solver, RANS and LES) to simulate disturbed blood flow in patient-specific geometries of the stenosed carotid bifurcation. By comparing crucial parameters and flow patterns, the results can be cross-validated using existing 4D flow MRI data and data from direct numerical simulations (DNS).



Qualitative comparison of streamlines between MRI and flow simulation at a healthy carotid bulb

Tasks	**Duration**
Conduct a comprehensive literature review (hemodynamics, 4D flow MRI, patient-specific simulations).	2 weeks
Familiarize with the flow field solver (OpenFOAM), analysis methods, and post-processing tools.	3 weeks
Generate mesh on a realistic geometry of carotid bifurcation (with stenosis) obtained from 4D flow MRI data.	1 week
Perform simulations using both idealized and patient-specific inflow boundary conditions.	4 weeks
Perform simulations using different approaches (laminar, RANS and LES) to simulate blood flow.	6 weeks
Analyze numerical flow data and extract relevant information (e.g., wall shear stress).	4 weeks
Write report	4 weeks

Requirements

Potential candidates should have a keen interest in numerical simulations.

A fundamental knowledge of computational fluid dynamics and programming (C++, MATLAB/Python).

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