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ABSTRACT TITLE
Vortex dynamics in cerebral aneurysm flow

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ABSTRACT

Introduction Cerebral or intracranial aneurysms are localized, thin walled dilatations of the arteries in the brain. The major risk involved is rupture of the aneurysm, resulting in a subarachnoid hemorrhage. In order to better decide whether or not and how to perform clinical intervention, the risk of rupture should be determined more accurately than currently possible. It is hypothesized that the risk of rupture is related to aneurysm geometry as well as to local hemodynamics. The aim of our research is to analyse intra-aneurysmal vortex patterns and identify candidate hemodynamical parameters (e.g. vortex strength) that are predictive for rupture risk and hereby improve its clinical assessment.

Methods To obtain patient specific hemodynamic parameters, x-ray based methods to measure the flow in the parent artery *in vivo* are being developed. In order to validate these methods *in vitro* experiments are carried out. Hereto, both x-ray and particle image velocimetry (PIV) experiments have been performed in idealized and patient specific aneurysm models.

In addition to the experimental methods, patient specific computational methods, based on finite element approximations, are used to determine the intra-aneurysmal velocity field. Boundary conditions are based on the flow data and 3D geometries from the *in vitro* experiments. This yields additional information required for the analysis of the 3D velocity fields. Hereto, suitable vortex identification schemes are implemented and used to identify candidate clinical parameters.

Results A computational model based on a standard Galerkin finite element approximation and an Euler implicit time integration has been applied and has been validated using the PIV results. The intra-aneurysmal velocity fields within both idealized and patient specific geometries reveal complicated 3D velocity fields (see figure 1) with complex vortical structures. In order to analyze these vortices, a vortex identification scheme based on the second eigenvalue of $\mathbf{S^2} + \mathbf{\Omega^2}$ is applied. Here $\mathbf{S}$ and $\mathbf{\Omega}$ represent the symmetric and anti-symmetric part of the velocity gradient tensor respectively [1].

Conclusions In order to gain better understanding of the hemodynamical factors involved in intra-aneurysmal flows, a thorough analysis of the velocity field within an idealized geometry is performed using both experimental and computational methods. In the presentation the focus will be on the CFD model and the analysis of the intra-aneurysmal vortices.

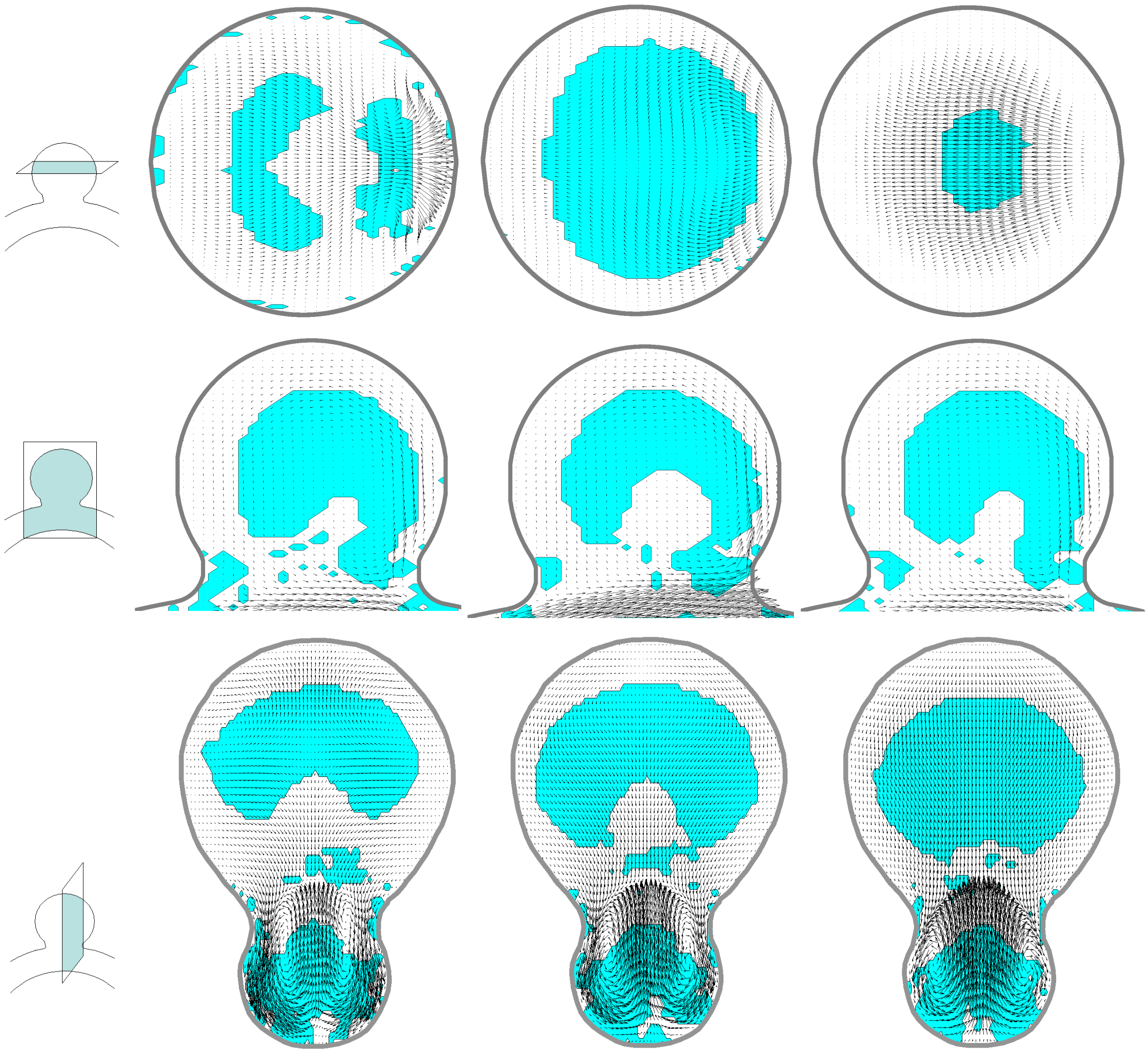

Figure 1: Velocity vectors and vortex structures in horizontal out-of-plane (top), in-plane (mid) and vertical out-of-plane (bottom) cross-sections through the aneurysm. Detection of the vortex core is achieved using a vortex identification scheme based on the second eigenvalue method developed by Jeong and Hussain[1]. Note that the outline drawn here corresponds to the wall at its maximum diameter (middle column), not to the wall at the actual cross-section (left and right column).

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