Multi-dimensional modelling of flow dynamics in cerebral aneurysms

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Introduction

Background: Cerebral aneurysms are localized, thin walled dilatations of the arterial wall in the brain (fig 1, purple). The major risk is rupture, for which a parametric estimate is sought.

Strategy: A validated 1D wave propagation and 3D Computational Fluid Dynamics (CFD) model (red) are combined in order to make full use of each model's strength (fig 2). A biomechanical analysis of flow and stress (blue) based on patient-specific input (green) is used to improve the diagnostics (blue).

Materials and methods

1D model: Integration of the Navier-Stokes equations over the cross-sectional area results in a 1D wave propagation model of the global cerebral arterial tree [2]. A spectral element method is used to solve the resulting set of equations for the pressure and flow waves. Boundary conditions are derived from patient-specific pressure and flow data.

3D model: Locally, an aneurysm model is defined by its patient-specific geometry (X-ray) and boundary conditions (1D model).

Validation: Particle Image Velocimetry (PIV) is used to validate the 3D CFD model.

Results

Quantitative agreement is obtained for PIV and CFD (fig 3).

Conclusion

The 1D model has developed, and the 3D model has been developed and validated by PIV experiments. Future research will focus on the acquisition of patient-specific data, virtual angiography and stress analysis.

References