MULTIMODAL IMAGING FOR THE PATIENT-SPECIFIC ASSESSMENT OF NEUROVASCULAR HEMODYNAMICS

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Introduction

With rising computational resources and higher modeling accuracy the application of image-based blood flow simulations to improve the understanding of cardio- and neurovascular diseases drastically increased over the last decade. However, in most numerical studies the focus is set on limited regions of interest and although they claim to be patient-specific, the modeling only includes a rigid segmentation of the individual vessel lumen [1].
To overcome the strong variability of hemodynamic simulations and regain the trust of the medical community in advanced modeling approaches, a standardized and holistic approach is needed [2].

Methods

Since the accuracy of hemodynamic simulations strongly depends on the imaging resolution, segmentation algorithm and individual image processing experience, high effort is put into a precise and multimodal image acquisition. This includes time-of-flight magnetic resonance imaging (MRI) and digital subtraction angiography (DSA) to capture the arterial vessels and magnetic resonance venography (MRV) for the venous part. Additionally, 2D phase-contrast MRI acquires real patient-specific volume flow rates [3] that are used as boundary conditions for multi-scale modeling [4]. Finally, a robust and reproducible workflow was established ensuring the generation of reliable numerical predictions.

Results

As shown in Fig. 1., highly resolved image-based based blood flow simulations could be carried out using both patient-specific vessel segmentations and boundary conditions. Exemplarily, the flow reduction in a wide-neck bifurcation aneurysm treated with a novel Contour device, the shear distribution of an arteriovenous malformation (AVM) and the pressure drop along a sinus stenos are presented.
Compared to recent studies focusing on limited regions of interest clear advantages of the multimodal approach could be identified. This includes 4D flow fields that allow for a risk-free evaluation of the disease state as well as supports the development of novel treatment approaches and their respective approval.

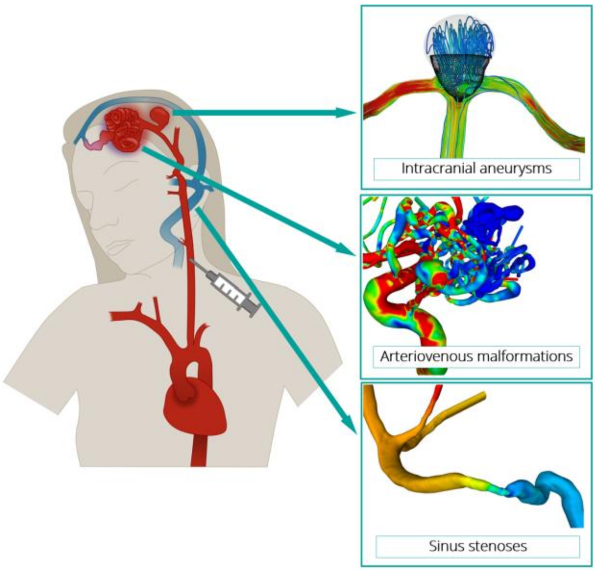

Figure 1: Schematic illustration of multimodal imaging for arterial and venous neurovascular diseases. Patient-specific modeling is used for individualized risk assessment and improvement of treatment planning.

Discussion

The combination of multiple modalities enables a more robust numerical assessment and the consideration of relevant vascular pathologies. Hence, detailed flow investigation of so far unknow hemodynamic interactions becomes possible, e.g., the analysis of enhanced AVM draining veins [5].
Future work includes further verification and validation of individual processing steps to strengthen the trust among physicians.

References

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