# MR-BASED MODELING OF INTERVENTIONS IN BASILAR ARTERY ANEURYSMS

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## Introduction

Untreated giant or fusiform aneurysms of the basilar artery present a grave danger of hemorrhage, cerebral compression, and thromboembolism. Interventional treatment of basilar aneurysms is particularly challenging since these lesions cannot be completely removed from the circulation without sacrificing flow to the vital pontine perforators. The alternative is an indirect aneurysm occlusion, consisting of a proximal or distal occlusion, sometimes performed with a bypass supplying flow from collateral circulation. The goal of intervention is to alter the pathological flow in the hope that this will inhibit aneurysm progression. We report on numerical simulations that use Computational Fluid Dynamics (CFD) models based on MRA/MRI data to assess different alternative surgical options.

## Methods

Contrast-enhanced MRA images acquired prior to intervention are used to generate 3D models of the aneurysmal vessels. To obtain the inflow conditions required for patient-specific CFD simulations, the flow through each vertebral artery (VA) is measured with phase-contrast MRI. The flow equations are solved numerically with the finite-volume solver Fluent. Preoperative flow computations are validated by comparison to in vivo 4D PC-MRI measurements. The model is then modified to include the proposed intervention, e.g. vessel occlusion and bypass. The flow in the postoperative geometry is then computed and flow descriptors affecting aneurysm progression, such as shear stress and flow residence time are predicted for a given treatment scenario.

## Results

Patient 1 presented with a partially thrombosed, giant basilar aneurysm (Fig.1 a). Preoperative flow measured with 4D PC-MRI is shown in Fig.1 (b). In order to alter the flow through the aneurysm, occlusion of one or other of the supplying VA's was considered. CFD simulations were conducted for each treatment option (left or right VA occlusion). The numerical results predicted that clipping the left VA (Fig.1 c) would result in a strong jet entering the aneurysm. If the right VA is clipped (Fig.1 d), the jet flows into the basilar trunk, while a part of it is deflected by the wall into the aneurysmal sac, resulting in a slowly rotating vortex. The later scenario is likely to promote aneurysm clotting, provided the fraction of the flow entering the aneurysm can be eliminated. This patient was treated by a stent-assisted coiling: a stent connecting the left VA with the proximal basilar ensured the coils are remaining in the aneurysmal sac,



thus preventing the jet from entering the lesion. The resulting 3D reconstruction based on XA-fluoroscopy is shown in Fig 1(e).
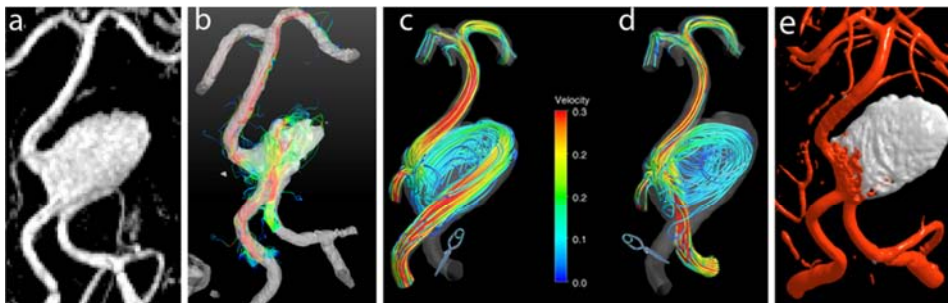
**Figure 1** Patient 1: (a) MRA MIP image; (b) Preoperative streamlines obtained in vivo with 4D MRV. CFD-predicted flow streamlines resulting from clipping left (c) or right (d) VA, and (e) postoperative 3D XA-reconstruction.

Patient 2 presented with a fusiform vertebro-basilar aneurysm (Fig.2 a). Alternative treatment scenarios were modeled with CFD in order to evaluate which option results in maintaining the patency of pontine perforators. A transport of virtual contrast was numerically simulated for preoperative (Fig.2 b) and postoperative (c) and (d) flow conditions. Each surgical option included a bypass from one of the VA's to the PCA in order to provide flow to the basilar apex and distal vasculature. In option (c), the dominant VA was clipped distal to the bypass. In the option (d), the contralateral VA was clipped in addition to clipping the distal basilar proximal to the apex, in the hope the flow would split between the basilar apex and perforators. Both models predicted a substantial fraction of the flow going through the bypass, resulting in reduced flow through the basilar. The option (c) results in a retrograde filling of the distal basilar. Based on these results, both models predicted substantially increased residence time in the distal basilar, which could lead to obstruction of the vital perforators with thrombus.

**Figure 2** Patient 2: (a) MRA MIP image; CFD-simulated virtual contrast transport for: (b) preoperative conditions; (c) flow resulting from clipping dominant VA and adding VA-PCA bypass and (d) flow resulting from clipping contralateral VA and distal basilar and adding VA-PCA bypass.
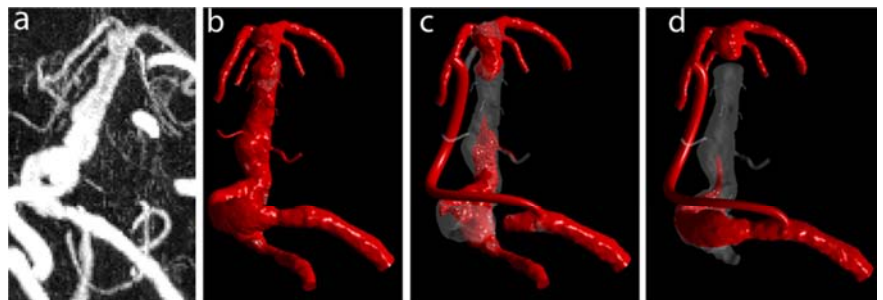


## Conclusions

The results indicate that CFD models constructed from MRI/MRA data can be used to predict postoperative flow in basilar aneurysms. This information, available prior to surgery, may help improve the outcome of vascular interventions.