Patient-Specific Computational Modeling of Cerebrovascular Hemodynamics

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OBJECTIVE

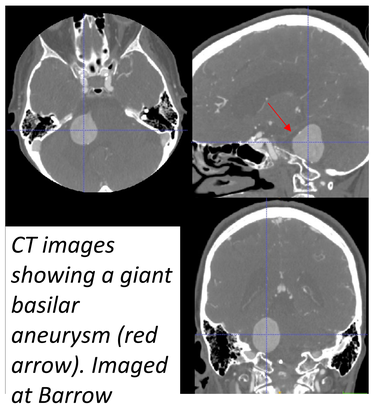
- Image-based computational modeling of cerebrovascular flows can provide quantitative data to aid clinical decision-making.
- We are developing **a framework for modeling patient-specific hemodynamics** in order to provide clinically-relevant quantitative descriptors that cannot be obtained from imaging.

We can evaluate postoperative flow conditions that would result from alternative surgical options with image-based CFD models.

METHODS

1. Models generated from MR, CT, and/or rotational X-ray angiography data using ITK-Snap
2. Blood flow computed FEM via open-source package SimVascular
   - Unstructured tetrahedral mesh generated from imported STL.
   - Boundary conditions in the presented case studies are assumed based off of the literature, but would be measured in patient-specific cases.
3. "Virtual surgery" performed on the model and post-operative flow conditions determined
4. Hemodynamic parameters known to influence arterial wall remodeling and intra-luminal thrombus deposition (e.g. wall shear stress, oscillatory shear index, etc.) are compared by averaging over the last cardiac cycle.

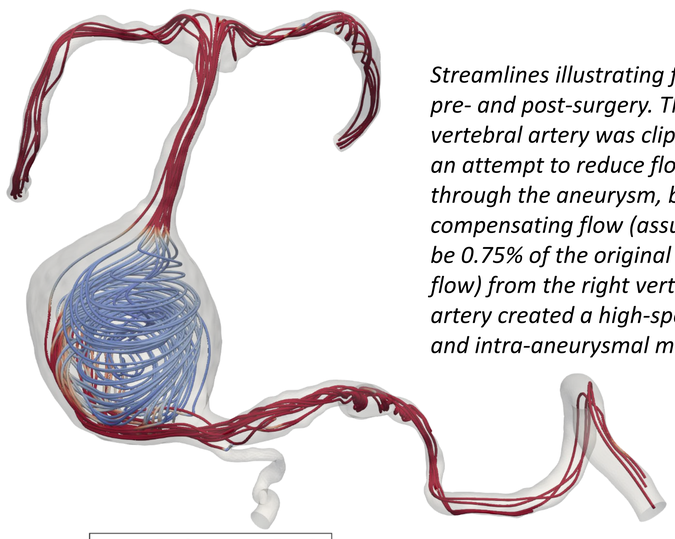
Case Study 1: Giant Basilar Aneurysm



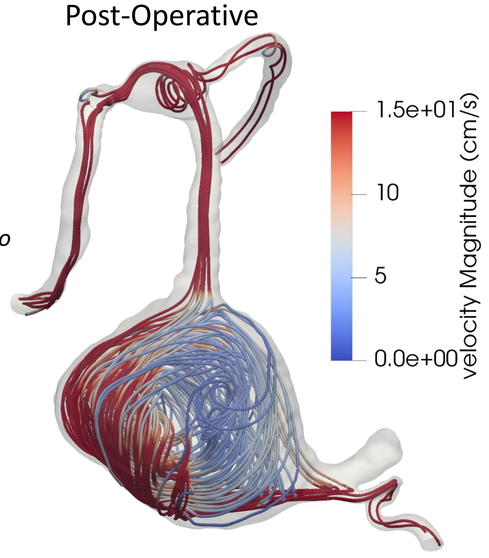
CT images showing a giant basilar aneurysm (red arrow). Imaged at Barrow Neurological Institute

3D model of aneurysm and surrounding vasculature prior to surgery.

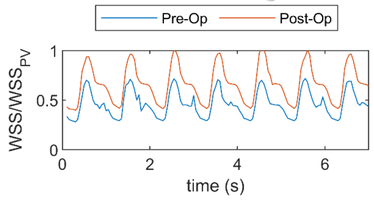
Pre-Operative



Post-Operative



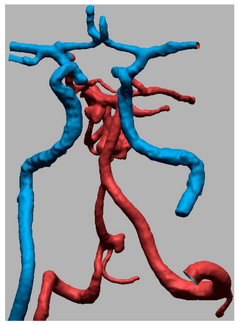
Streamlines illustrating flow pre- and post-surgery. The left vertebral artery was clipped in an attempt to reduce flow through the aneurysm, but the compensating flow (assumed to be 0.75% of the original total flow) from the right vertebral artery created a high-speed jet and intra-aneurysmal mixing.



Average wall shear stress normalized by the averaged parent wall shear stress at systole pre- and post-surgery

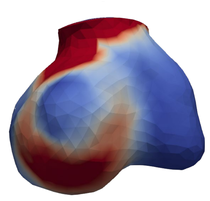
Case Study 2: Flow-Related Arteriovenous Malformation

X-ray angiography showing a right superior cerebellar AVM (red arrow) and two flow-related aneurysms (R PICA, black arrow, and R superior cerebellar, white arrow). Imaged at IUSM

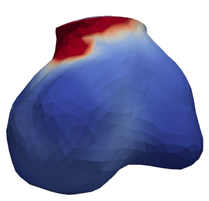


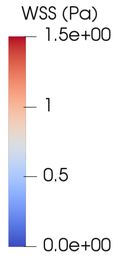
3D model of anterior (red) and posterior (blue) circulation.

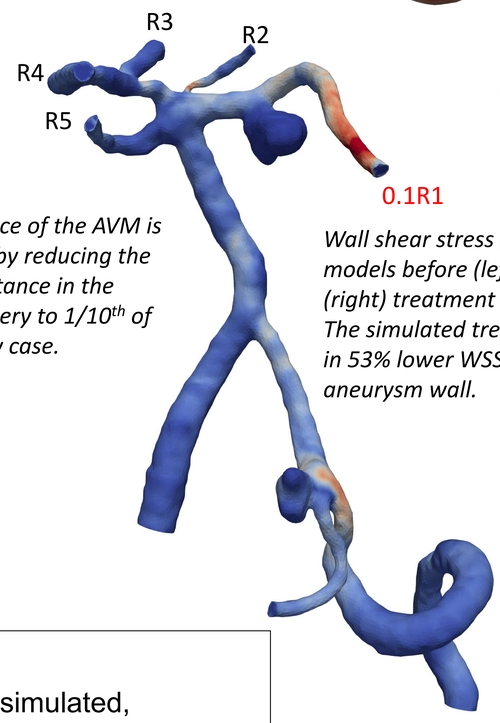
Pre-Operative



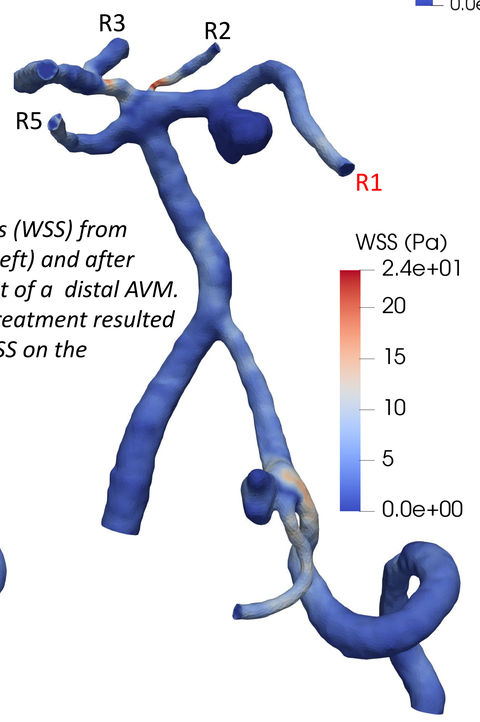
Post-Operative







The presence of the AVM is simulated by reducing the distal resistance in the feeding artery to 1/10th of the healthy case.



Wall shear stress (WSS) from models before (left) and after (right) treatment of a distal AVM. The simulated treatment resulted in 53% lower WSS on the aneurysm wall.

CONCLUSIONS

The hemodynamic impact of surgical procedures can be simulated, providing clinicians additional information to consider when developing a treatment plan for patients with cerebrovascular lesions.