Cerebral Perfusion Analysis Using Computational Modeling of the Brain and its Arteries

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INTRODUCTION

- The cerebral region's ability to govern complex cognitive processing is dependent on an ample supply of oxygen and nutrients to the brain through a dense network of cerebral blood vessels.
- It is crucial to understand normal and abnormal brain perfusion along with contributions of blood vessels for analysis of cerebral diseases.
- The purpose of this research is to propose a 3D-modeling based methodology to simulate normal and abnormal cerebral blood flow and its correlation to brain perfusion.
- **We employed modeling of brain vessels and tissues, and correlated with computational fluid dynamics (CFD)**

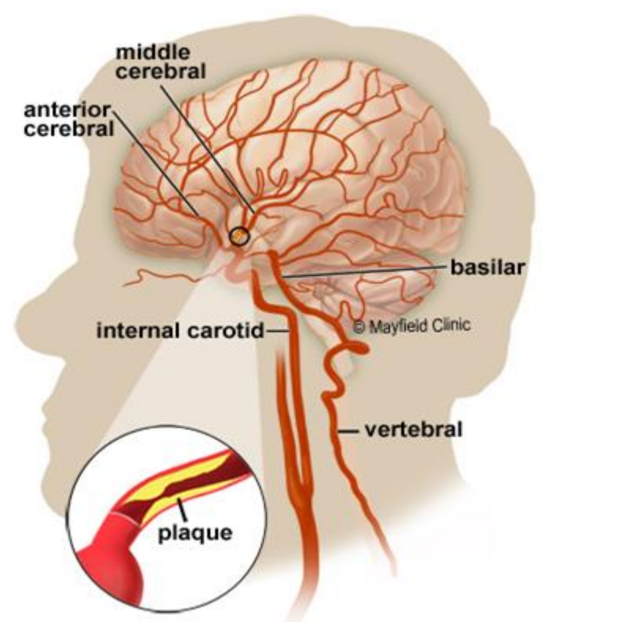

Figure 1. Schematic of narrowed or blocked cerebral vessel (possible causes for ischemia, dementia, chronic migraines, and brain tissue damage).

https://mayfieldclinic.com/pe-intracranialstenosis.htm

METHODOLOGY

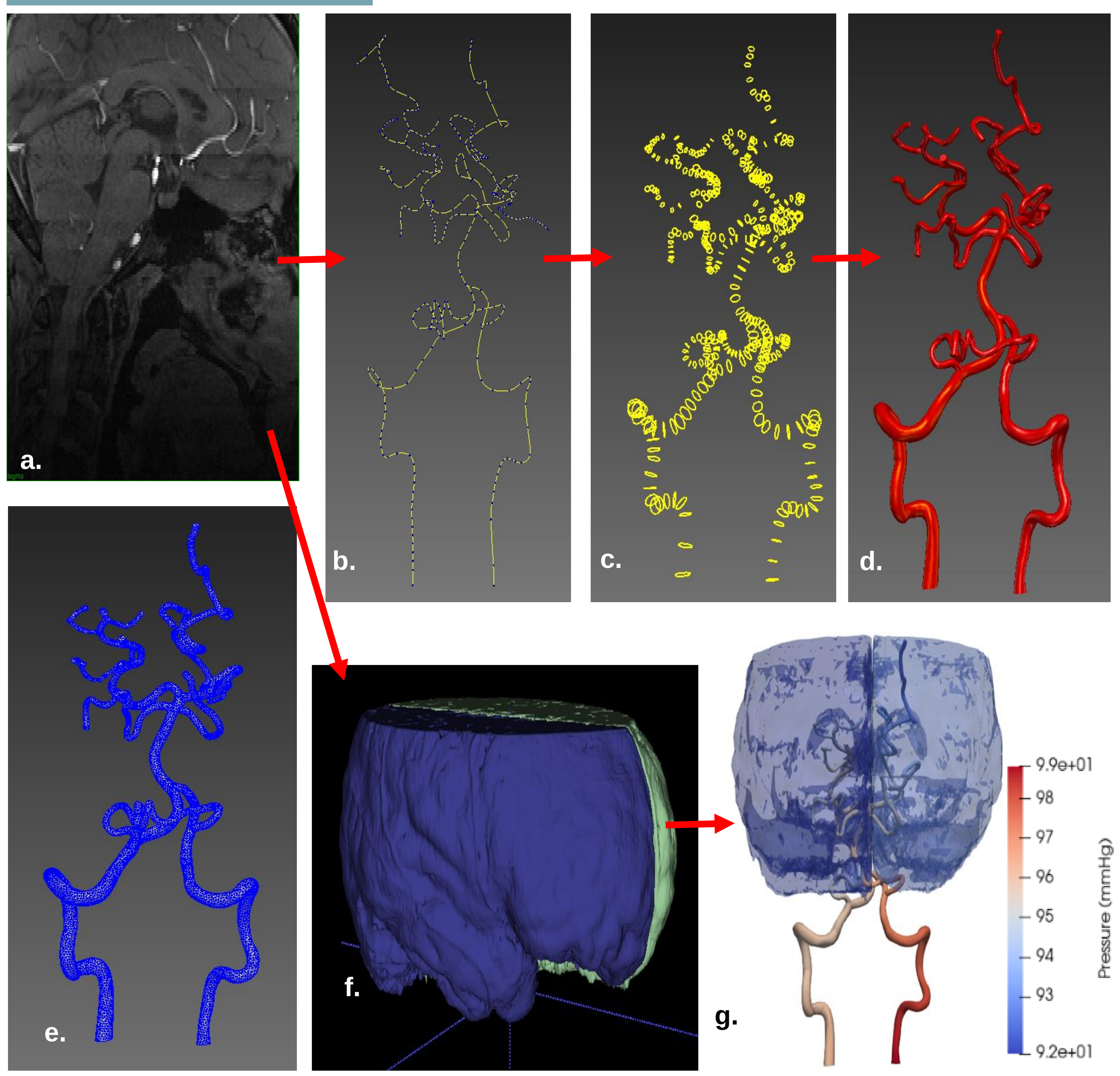

Figure 2. Components of 3D-modeling for cerebrovasculature and brain tissue:

(a) Subject's image data including head, (b & c) vessel path and segmentation, (d) 3D model creation of the vasculature, (e) model mesh creation to run CFD analysis (f) ITK-SNAP brain segmentation of left and right hemispheres, (g) co-registration of the 3D models of the cerebrovasculature and brain tissue.

Eight different cases were utilized to complete joint modeling of cerebral arteries and brain hemispheres.

Computational fluid dynamics revealed physiologic pressure distribution for a normal subject case.

Scan QR code for more information about this research

RESULTS

- Anonymized human imaging data (1 male and 5 females) was utilized for this study. The two females exhibited cerebral aneurysms, with pre and post-stenting image data. In total, we modeled cerebrovascular and brain tissues for 8 cases (6 native and 2 post-op).

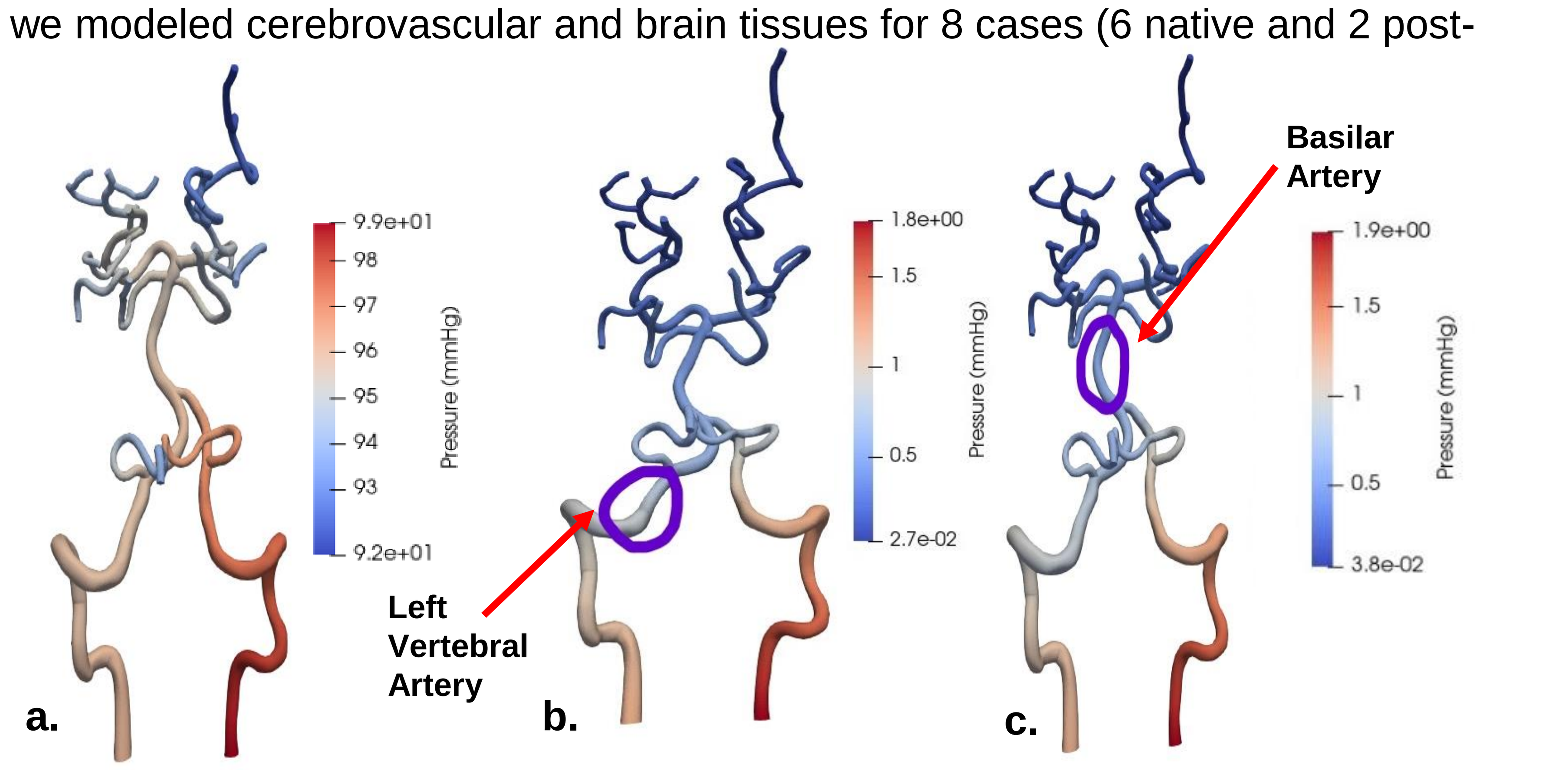

Figure 3. Simulation result of Subject 1: pressure range for normal model and artificial abnormalities: (a) simulated pressure of a healthy subject model, (b) 20% decreased area in the Left Vertebral Artery (LVA), (c) 20% decreased area in the Basilar Artery.

- Our results indicated a drastic decrease in blood pressure in the case with abnormalities with the small changes made to the area of the LVA.

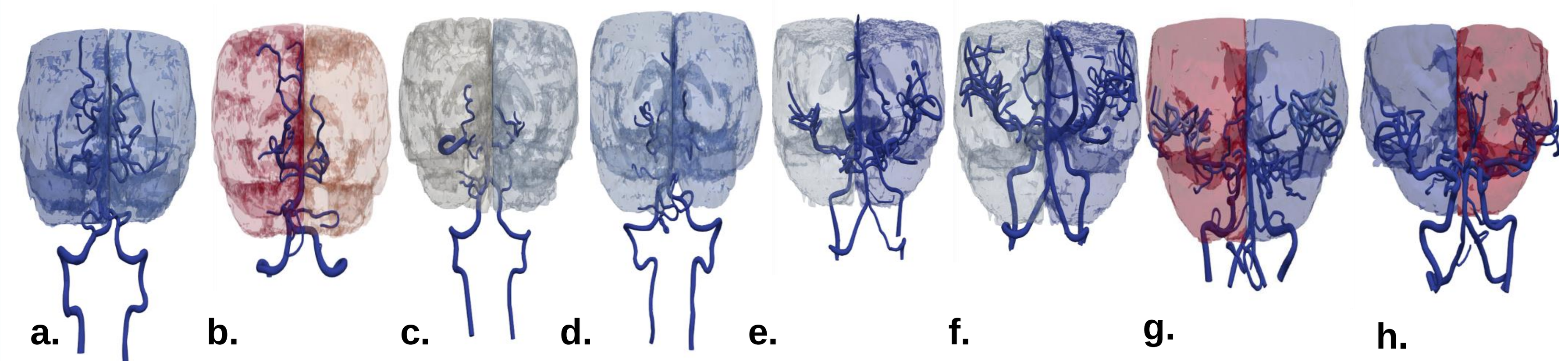

Figure 4. Co-registered cerebrovasculature and brain models:

(a) Subject 1, (b) Subject 2, (c) Subject 3, (d) Subject 4, (e) Subject 5 preop, (f) Subject 5 postop, (g) Subject 6 preop, (h) Subject 6 postop.

- This co-registration visualizes spreading of cerebrovasculature inside the brain volume to perfuse the blood flow. We observed even distribution of vessels to the left and right, except Subject 5 preop.

FUTURE WORK

- Brain tissue models will be differentiated by lobes in order to understand perfusion percentage of each lobe and correlation to the lobe volume. This will provide further insight of cerebral perfusion with or without cerebral abnormalities.
- This research study plans to produce a 3D-printed in-vitro model of cerebrovasculature and brain tissues for palpable visualization.
- CFD analysis will continue to troubleshoot pressure estimation after introducing abnormalities to the normal model, after trials of different boundary conditions.

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