Numerical Model to Remove Thromboemboli Using Aspiration Thrombectomy

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Summary

Acute ischemic stroke (AIS) is a major cause of mortality and morbidity globally. Typical treatment methods include thrombolytic therapy and mechanical thrombectomy. Unfortunately, there are cases where neither approach works effectively. Thus, having a computational platform that investigates AIS may lead to improved outcomes. In this study, we present ongoing efforts towards this end, which include modeling thromboembolus removal.

Introduction

In AIS, recanalization failures are partly linked to the mechanical properties of blood clots and are difficult to study experimentally. Blood clots are often modeled as hyperelastic materials, and in some cases contain viscous contributions. We have focused on developing experimental thromboemboli analogs and determining physically meaningful material parameters for models that can be used in finite element calculations, and the effect on the outcomes of endovascular thrombectomy procedures.

Methods

In silico calculations were performed to determine the equilibrium state of an artery with a residual stress state common to all arteries, and with a clot lodged in such a way that it compresses into the arterial wall. An aspiration pressure was applied at the proximal end of the clot until tensile displacement of the clot-artery interface was observed.

Results and Discussion

High strain data showed a significant increase in compressive and tensile tangent moduli for a hyper calcified clot phenotype. The increase in stiffness, and decreases in porosity observed in these clots suggest a clot phenotype that is prone to fracture. The *in silico* results demonstrate that the initial dimensions of the clot, among other conditions, play a large role in the outcomes of thrombectomy, and namely, the aspiration pressure necessary to begin removing the clot (Figure 1).

Conclusions

Overall, the implication from these studies is that new therapeutics may need to be developed to deal with mineralized clots, and clot dimensions need to be taken into consideration, when possible, to determine the effective operating parameters for thrombectomy procedures.

Acknowledgments

This work was supported, in part by funding from the United States National Institutes of Health (NHLBI) through NIH Grant HL146921, US NIH (NIGMS) T32 Physiological Adaptations to Stress Grant T32GM108563, the Penn State Clinical Research Center in the Clinical and Translational Science Institute, the Penn State Huck Institutes' Microscopy Core Facility (RRID: SCR_024457), an Alfred P. Sloan Scholarship and a Gates Millennium Scholarship.

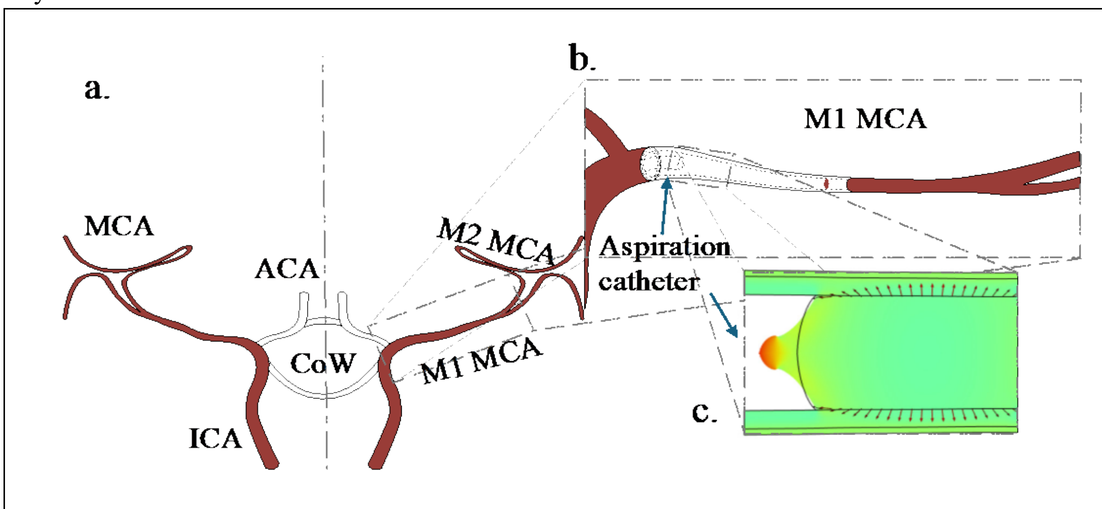

Figure 1: a. Diagram of the central cerebral circulation with internal carotid arteries (ICAs), anterior cerebral arteries (ACAs), middle cerebral arteries (MCAs), and Circle of Willis. (CoW) b. Zoomed in view of the M1 segment of the MCAs, with a lodged clot and an aspiration catheter and c. the representative two-layered arterial section used in the computational domain, located at the proximal end of the M1 MCA. The results show traction vectors of the clot pressing into the arterial wall and detaching near the aspiration catheter. Figures are not to scale, exaggerated for illustration purposes.