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A Viscoplastic Theory of Saccular Aneurysm Enlargement and Growth

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Aneurysms are common, life-threatening, and poorly understood. It is nearly impossible to observe the disease process which leads to aneurysms, especially in early stages. As a result, little is known about causes of the disease, and there is no strongly-correlated marker of patient prognosis.

There is an extensive literature of arterial modeling built from microscopy and Biomechanical testing. Continuum theories have been utilized as first principles to describe the kinematic progression of the disease from some initial insult. This has worked acceptably well for fusiform aneurysms, but cannot explain the etiology of 90% of (diagnosed) intracranial aneurysms--saccular aneurysms. We propose a methodology to evaluate and improve the above material models for the saccular aneurysm case.

We use a viscoplastic theory to model growth. Disease is defined as a local reduction in yield stress; the aneurysm forms when irreversible strain occurs. The viscoplastic theory has similarities with the popular notion of turnover and return to homeostasis, and differs in two fundamental ways: it allows more radical deviations from homeostasis, sidesteps several fundamentally-limiting kinematic constraints, and has the capability to model saccular aneurysms.

We also recognize and define separate disease stages--asymptomatic, stable symptomatic, unstable, and hemorrhagic--and we establish biomechanics terminology and definitions for each.

We use isogeometric analysis. It utilizes the same basis functions representing the geometry that are used in the approximation of the unknown solution fields. It possesses several advantages in terms of accuracy, robustness and higher-order continuity. It is successful in a broad range of applications in computational mechanics, from fluid dynamics to structural problems.

The modeling system involved in this work is a necessary step to provide better conclusions as to the behavior and mechanical nature of diseased arteries, as well as to improve the overall predictive capability of simulation tools. Physicians who use these tools will better understand aneurysm dynamics, improve their morbidity and mortality rates, and save lives.