On the biomechanics of the initiation and growth of intracranial aneurysms

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Abstract

Intracranial aneurysms (ICA) are abnormal saccular dilations of cerebral arteries, commonly found at apices of arterial bifurcations and curved segments of arteries at the base of the brain. If untreated, an ICA can continue to expand until rupture, resulting in hemorrhage which is followed by death or severe disability in the majority of patients. Screening and preventative treatment strategies are notably absent in the clinical handling of this disease. This is in stark contrast to other diseases such as atherosclerosis, in which detailed knowledge of the pathobiology is instrumental in establishing screening procedures and developing effective pharmaceutical treatments such as statins. ICA are only identified prior to rupture in approximately 10% of the cases. As a result, little information is known about the initiation and growth process.

In the first part of this talk, we discuss several theories regarding the initiation process and evidence to support or dispute these theories. Previous biomechanical modeling of aneurysm behavior focused on deformations of a preformed aneurysm. In these studies, the aneurysm tissue was treated as a different entity than the arterial tissue from which it developed. The size, shape, thickness, anisotropy and inhomogeneity of the undeformed reference configuration are specified. In the second part of this talk, we discuss a new constitutive

equation for cerebral arterial walls that employs multiple reference configurations to model the structural changes that occur during early stages in the formation process [1]. This constitutive equation is motivated by mechanical and histological tests on cerebral arterial tissue that suggest the development of cerebral aneurysms is tied to the recruitment of collagen fibers and breakage of elastin and collagen in the original arterial wall [2, 3]. We have recently extended this model to include anisotropy of the cerebral wall due to fiber orientation [4]. In addition, this model includes, for the first time, hemodynamically induced breakdown of the IEL [5]. We have used this constitutive equation to model the development of an early stage aneurysm, or bleb. Results from this study are consistent with clinically observed characteristics of aneurysm development.

Keywords: Cerebral aneurysm, constitutive model, anisotropic, soft tissue.

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