Hemodynamics and Structural Analysis of Aneurysms with Known Rupture Sites

Juan R. Cebral, George Mason University

It is thought that aneurysms evolve as the result of progressive degradation of the wall in response to abnormal hemodynamics characterized by either high or low wall shear stress (WSS). Our goal is to investigate the effects of these two different hemodynamic pathways in a series of cerebral aneurysms with known rupture sites. A total of nine aneurysms in which the rupture site could be identified in 3D images were analyzed. The WSS distribution was obtained from computational fluid dynamics (CFD) simulations. Wall stresses were computed using structural wall models under hemodynamic loads determined by the CFD models. Wall properties (thickness and stiffness) were modulated with the WSS distribution (increased or decreased in regions of high or low WSS) to test possible wall degradation pathways. Rupture probability indices (RPI) were calculated to compare different wall models. It was found that rupture sites tended to be aligned with the intrasaccular flow stream and downstream of the primary impaction zone. The vascular wall model that best explained the rupture site (produced higher RPI) in 8 of the 9 aneurysms (89%) had thinner and stiffer walls in regions of abnormally high WSS. The remaining case (11%) was best explained by a model with thinner and stiffer walls in regions of abnormally low WSS. In conclusion, aneurysm evolution seems to be driven by localized degradation and weakening of the wall in response to abnormal hemodynamics. Image-based computational models assuming wall thinning and stiffening in regions of abnormally high WSS were able to explain most of the observed rupture sites.