Individual anisotropic FSI modeling of aortic aneurysms: phase-contrast and dynamic MRI validation

S. Chandra[1], A. Jana[2], and E. Finol[1]

[1]Carnegie Mellon University, Pittsburgh, PA, [2]Pittsburgh Supercomputing Center, Pittsburgh, PA

Retrospective studies reveal that nearly 33% of ruptured aneurysms have a maximum diameter less than 5 cm. This challenges the use of size in rupture risk assessment and provides the opportunity for further research on alternate parameters for rupture potential criteria. We propose the use of patient specific fluid-structure interaction (FSI) models to investigate the potential of individual flow-induced wall stress as the key biomechanical determinant for at-risk evaluation. A computational protocol is developed where patient specific FSI inflow and outflow boundary conditions are derived from individual phase-contrast MR images of subjects eligible for elective repair. The distribution of AAA wall thickness is obtained from individual spin echo MR images and accounted for in the FSI model. ECG-gated cine MRI scans are used to derive the baseline geometric model and to calculate the unstressed initial geometry for the generation of the finite element mesh. Anisotropic constitutive material models are used for the AAA wall and ILT domains. The flow patterns are validated by comparison with the phase-contrast MR velocity measurements at the midsection of the AAA, while wall displacements are validated with the cine MR images. The inclusion of the non-uniform wall thickness yields a 40% higher peak wall stress when compared to that predicted by a uniform 1.5 mm thick wall. Moreover, the unstressed finite element model predicts a 20% lower peak wall stress when compared with the stress resulting from the AAA geometry stressed at end-diastolic pressure.