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# Fluid-Structure Interaction Human Carotid Plaque Progression Simulation Using 3D Meshless Generalized Finite Difference Models Based on Patient-Tracking In Vivo MRI Data

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## Summary

Cardiovascular disease is the leading cause of death worldwide. Many victims of the disease died suddenly without prior symptoms. It is a great challenge for clinicians and researchers to develop screening techniques and assessment methodologies to identify those patients for early treatment and prevention of the fatal clinical event. Considerable effort has been devoted investigating mechanisms governing atherosclerotic plaque progression and rupture [Friedman, Bargeron, Deters, Hutchins and Mark (1987); Friedman and Giddens (2005); Giddens, Zarins, Glagov, S. (1993); Ku, Giddens, Zarins and Glagov (1985); Gibson et al. (1993); Liu and Tang (2010); Stone et al. (2003); Yang, Tang, Atluri et al. (2008,2010)]. Previously, we introduced a computational procedure based on three-dimensional meshless generalized finite difference (MGFD) method and serial magnetic resonance imaging (MRI) data to quantify patient-specific carotid atherosclerotic plaque growth functions and simulate plaque progression. Structure-only models were used in our previous report [Yang, Tang, Atluri et al. (2010)]. In this paper, a meshless modeling procedure for fluid-structure interaction (FSI) human carotid plaque progression simulation using 3D generalized finite difference (GFD) models was introduced based on multi-year patient-tracking in vivo magnetic resonance imaging (MRI) data. Multi-year patient-tracking data was obtained three times (T1, T2, and T3, at intervals of about 18 months) to obtain plaque progression data after informed consent. Blood flow was assumed to laminar, Newtonian, viscous and incompressible. Plaque material was assumed to be uniform, homogeneous, isotropic, linear, and nearly incompressible. Meshless GFD FSI models were constructed and validated by ADINA for the plaque at T1, T2 and T3 to obtain plaque wall (structure) stress and flow shear stress to determine plaque growth functions which were used in progression simulation. Four growth functions with various combinations of morphology, plaque wall stress (PWS) and flow shear stress (FSS) were quantified using least-squares approximation and T1 and T2 data to fit T3 plaque morphology.

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Starting from the T2 plaque geometry, plaque progression was simulated by solving the FSI model and adjusting plaque geometry using plaque growth functions iteratively until T3 is reached. Numerically simulated plaque progression agreed very well with the target T3 plaque geometry with errors ranging from 8.62

**Keywords:** meshless, generalized finite difference, artery, plaque progression, fluid-structure interaction, atherosclerosis.

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