IN SILICO STUDY OF BLOOD FLOW AS BIOMECHANICAL DETERMINANT OF PLAQUE FORMATION AND LOCALIZATION

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Introduction
Atherosclerosis is considered as the pathological formation of fibrous and lipid-rich plaques in large arteries and, in part, is modulated by patterns of blood flow. Plaques have been observed to form preferentially at artery curvatures and bifurcations because flow fields among them are complicated [Mortazavinia, 2012]. Vascular wall shear stress (WSS) [Vincent, 2011] as well as oscillatory flow have been correlated to the development of atherosclerosis in arteries. Thus, the wall shear stress gradient (WSSG) and Oscillatory shear index (OSI) are consider as hemodynamic parameters related to plaque formation. New hemodynamic parameters are proposed and tested as possible indices for the prediction of plaques formation and localization.

Methods
The 3D geometry of the ascending artery was reconstructed by CT scan images. For cross comparison, different reconstruction methods were developed. For the anatomic representation a series of high resolution 2-D slice-based medical images of aorta in the length of interest, usually in the direction of vessel axes, which allows clearer definition of vessel lumen when acquired from CTA source images, was used. Then outlines of vessel lumen where extracted based on pixel intensity level by various algorithms such as region growing method or level set method, and then 3-D surface was reconstructed by stacking and interpolating those segmented contours. Surface smoothing procedure was conducted to a certain level.

The blood flow was mainly assumed to be pulsating, laminar, viscous and the fluid Newtonian and incompressible. More realistic blood flow models were also applied and studied. The governing equations of the flow
\[ \mathbf{v} \cdot \mathbf{q} = 0, \quad (1) \]
\[ \rho \frac{\partial \mathbf{q}}{\partial t} + \mathbf{p} \cdot \nabla \mathbf{q} = -\nabla p + \mu \nabla^2 \mathbf{q}, \quad (2) \]
were numerically solved using the commercial code ANSYS CFX for computational fluid dynamics.

Results

Discussion
It is proved that a relationship between WSS and atherogenesis may exist. Identification of WSSG, OSI and correlated indices conditions, that “facilitate” plaque formation, can significantly contribute to prevention of atherosclerosis-related morbidity and mortality. Therefore, accurate calculations of these hemodynamic parameters are required.

References