IN SILICO HEMODYNAMICAL SIMULATIONS SHOW SECONDARY BENEFITS OF ANTIHYPERTENSIVE DRUGS

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Introduction

Although preventable, hypertension and hypertensive renal disease remain one of the major global risk factors for cardiovascular diseases, especially in the developed world [1]. Hypertension is defined as a chronically increased blood pressure (BP) above 140/90 mmHg and is related to an increase in peripheral resistance and decrease in arterial distensibility [2], similarly to an aging [1]. Available evidence confirms the ability of all five basic groups of antihypertensives to decrease arterial stiffness and consequently the BP in the long-term application [3]. Although proper treatment of hypertension attenuates its influence, the mechanisms by which hypertension accelerates atherosclerosis are poorly understood [4]. It is known that flow waveform for older subjects differs substantially from the young one mainly due to elevated arterial stiffness and consequently early wave reflection [5]. Moreover, the decreasing arterial stiffness via proper treatment of hypertension shifts the shape of the flow waveform to a young and healthy one [6]. Since arterial stiffness can be lowered through long-term application of antihypertensives, benefits of medical therapy could be not only in lowering the BP and peripheral resistance but also in improving the hemodynamic conditions.

Methods

Three finite volume models of patient-specific geometries of human carotid bifurcations were created based on CT-A scans. Laminar blood flow was modelled in Ansys® Fluent® using Carreau model of non-Newtonian incompressible liquid. To avoid an unrealistic piston profile at the inlet, a 3D parabolic velocity profile was computed from volumetric flow boundary condition. In total, two different (old [5] and young [7]) archetypal flow waveforms were used. Three element Windkessel was imposed at each outlet. Its parameters (three per each outlet) were estimated via nonlinear least-squares optimization method to fit the measured flow waveforms. The estimation methodology was inspired by [8]. The computational domain was discretized in time with a step size of 0.003 s.

A time-averaged wall shear stress (TAWSS) together with a relative residence time (RRT) were used as hemodynamic indicators for the risk of atherosclerosis development. Regions are classified as atheroprone (from a merely fluid dynamic point of view) if TAWSS is < 0.48 Pa and RRT > 2.9 [9].

Results

Results were extracted from the 3rd cycle of transient 3D CFD simulations reaching a stabilized cyclic response. They show significant enlargement of the low TAWSS area (*i.e.*, below the threshold value) for the older archetypal waveform (see Fig. 1) while the RRT remains almost constant for all geometries.

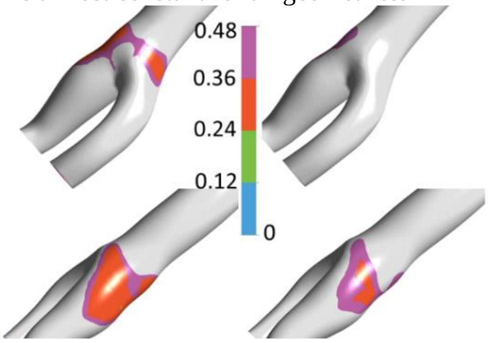

Figure 1: Maps of the time-averaged wall shear stress for one of the three patients. Results for the old (left) vs young (right) archetypal flow waveforms.

Discussion

Although low TAWSS is a necessary indicator of a plaque formation, it is not sufficient for reliable prediction of the future plaque location [10]. Since the low TAWSS region overlaps a region with oscillatory flow and high RRT, it seems that the significant decrease of the TAWSS caused by the old archetypal flow waveform may increase the risk of future atherosclerosis development, which is probably one of possible mechanisms how atherosclerosis is accelerated.

References

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