PREDICTION OF POST STENOTIC FLOW INSTABILITIES IN A PATIENT-SPECIFIC COMMON CAROTID ARTERY MODEL

Viviana Mancini[1*], Aslak Bergersen[2], Kristian Valen-Sendstad[2], Jan Vierendeels[3] , Patrick Segers[1]

[1]IBiTech – bioMMeda, Gent University, Belgium

[2]Scientific computing Simula Research Laboratory, Norway

[3] Department of Flow, Heat and Combustion Mechanics, Gent University, Belgium

Keyword(s): biomechanics – modeling of physiological systems

1. INTRODUCTION

The carotid arteries are the main vessels feeding the brain tissues and they are unfortunately very prone to develop atherosclerotic plaques close to the bifurcation. The growth of the plaques leads to the narrowing of the vessel, better known as stenosis. The severity of the stenoses in the internal carotid artery (ICA) strongly affects the blood flow towards the brain: a higher degree of stenosis leads to an higher risk of stroke. Furthermore, it is well known that the pulsatile nature of the flow in combination with narrowing of the lumen can cause post stenotic flow instabilities. The purpose of this study is to assess the relation between the turbulence level and the degree of stenosis in order to produce a turbulence-based threshold value for mild, severe and highly severe stenosis. This may open ways to diagnose stenosis severity from measurements of vibrations measured at the skin in the neck.

2. MATERIALS AND METHODS

CT images of a carotid bifurcation with 76% stenosis by area in the internal carotid artery [1] was manipulated by means of a VTK-based in-house code in order to reach 56%, 66%, 86% and 96% area stenosis. The five geometries were then meshed in 15M linear tetrahedral cells by means of VMTK. The flow split was set in order to mimic physiological values accordingly to the stenosis severity [2]. The pulsatile inflow was obtained by previously performed in-vitro experiments with a Reynolds number (Re_{peak}) of ~ 1400 with water. Simulations were performed by means of the 2nd order finite elements software Oasis [3].

3. RESULTS AND DISCUSSION

Results are shown for the 56%, 76% and 85% stenosis. The power spectral density (PSD) of the magnitude of the fluctuating velocity is plotted in logarithmic scale in Figure 2. The 56% stenosis behaves differently if compared with the more severe stenosis. It is not severe enough to induce a strong acceleration and then deceleration of the flow which hence behaves more like a laminar flow. The 76% stenosis is severe enough to trigger instabilities, but at a lower energy level than the 85% stenosis. These numerical results remain to be validated against hydraulic bench experiments and confirmed in vivo.

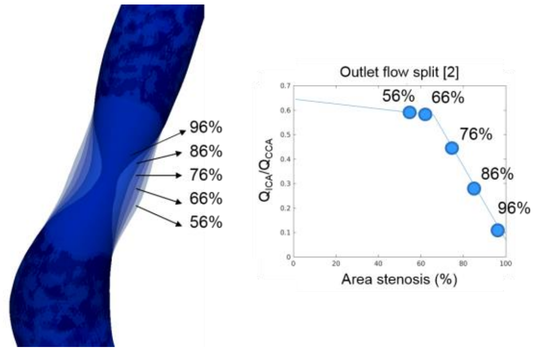

Figure 1: multiple degrees of stenosis and physiological flow split [2]

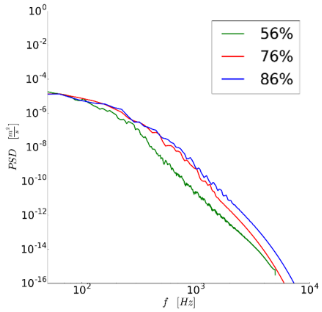

Figure 2: PSD of multiple degrees of stenosis

References

[1] *Int J Arg Org*, 37:928-939, 2014.

[2] *J Biomechs*, 43, 2332-2338, 2010

[3] *Comp Phys Comm*, 188, 177-188, 2015

[4] *Comp Phys Comm*, 188, 177-188, 2015