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STEADY STATE CAROTID FLOW IN-VITRO PIV MEASUREMENTS

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Abstract

The present paper deals with the experimental measurements of steady incompressible viscous flow in a human carotid artery and its branch. This

arterial tree, specifically the bifurcation of the common carotid artery (into the internal and external carotid arteries), is a well known site of atheromatous plaque formation. These plaques grow progressively leading to stenosis and can suddenly rupture causing instantaneous thrombi and emboli, thus infarction of irrigated tissues (stroke). Steady flow in the carotid artery occurs when the human heart, suffering from chronic heart failure, undergoes implantation of a small continuous-flow ventricular assist device (VAD). Abnormal wall shear stress, pressure and low washout regions may occur, which in turn could trigger plaque formation and growth [1, 2]. The finite-time Lyapunov exponent is used as a criterion to reveal the complex flow structure and is found to be efficient in discriminating between reverse flow and recirculation regions.

METHODS

The carotid geometry is presented in Fig. 1. The method for building the carotid model is similar to the procedure followed by Hopkins et al [3] to obtain a model of the human nasal cavity. An accurate model of the artery is first derived from MRI measurements (data obtained from INRIA). Based on scan data from different adjacent planes, a high resolution three-dimensional surface model is obtained. The resulting stereolithography file serves as the geometry to construct a solid model at a scale 3:1 using rapid prototyping technique. This prototype is made of starch whose porosity renders it watersoluble. The working fluid is seeded with fluorescent tracer particles (Rhodamin B) illuminated with a cw-diode pumped Q-switched double Nd:YAG laser, and two CCD cameras are synchronized with the laser pulses for stereoscopic measurements. The three components velocity vectors were calculated by averaging 800 data fields. To overcome the difficulty related to the identification of recirculation regions in complex flows, the finite-time Lyapunof exponent (FTLE) has been chosen [4]. Ridges of local maxima in the FTLE field act as material lines in the flow and reveal transport barriers between different regions in the flow. To determine the FTLE, the deformation gradient tensor has to be computed from the advection of fluid particles. The numerical procedure uses a second-order Runge-Kuta scheme integrating either the mean velocity or the time-resolved velocity fields in time-dependent applications.

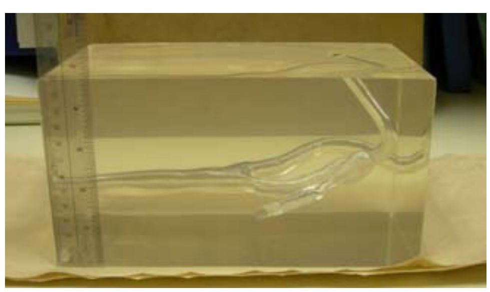

Figure 1: Silicon model of the carotid.

RESULTS

For a flow division of 3:7 (external carotid / internal carotid) a sharp boundary separates the cross section in two distinct regions (Fig. 2). When the flow rate through the internal artery is decreased to 50% the boundary is modified, mainly in the upper region. This results in a decrease of the cross-section area bounded by this boundary in the side of the internal artery. This would indicate that the boundary identified here could be linked to the flow division in the daughter branches, suggesting that when the flow rate through the internal artery is decreased, the additional amount of fluid flowing through the external artery comes from the sinus.

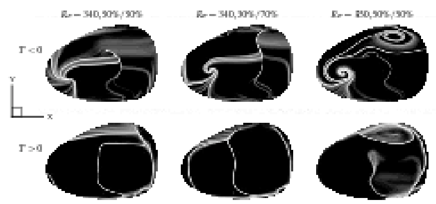

Figure 2: FTLE fields computed with the in-plane velocity components in a plane close to the bifurcation.

Key Words: *Carotid Silicon Model, PIV, Lyapunov exponent.*

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