A Numerical Study of The Hemodynamics In Common Carotid Artery with Vasodilation Affected by Different Shapes of Carotid Atherosclerotic Plaque

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***Abstract*— Stroke has been accounted for a major mortality and morbidity as a consequence of cardiovascular diseases. Stroke incidents are mainly caused by thrombosis which is the result of hemodynamic disturb and plaque ruptures. Especially, the dimensions of the plaque play an important role in flow flied distortion. Our study considers the position of throat in the stenosis, the narrowest region of the stenotic artery, as the main factor to investigate the hemodynamic variation in the carotid artery with vasodilation. The result showed that the distal throat has significant correlation with recirculation compare to the proximal throat.**

***Keywords*--- geometry, recirculation, vasodilation**

I. Introduction

The Numerical studies of geometry of the plaque effect on the blood flow field have been conducted both base on ideal shape constructions and patient specific imaging vessel reconstructions even though, as clinical statistics show that, there is no typical shape of plaque. Still, certain specific feature can be extracted from all kinds of variations. Previous studies mostly focus on the severity of the plaque, size and eccentricity in either single vessel or bifurcation models [1-3]. In our study, we take the narrowest position of the stenosis, known as the throat, as the main factor to investigate the flow distortion in the carotid artery with vasodilation phenomena.

II. Method

1) Geometry configurations

Two 2D geometries of stenotic arteries are illustrated; one is reconstructed based on the measurement of the specific features from the B-mode Ultrasound image and another is by modifying the position of the throat with other features are preserved (Figure.1).

Figure 1 Geometries of the distal throat model (left) and the proximal one (right), the position criteria is based on the flow direction (from the right to the left.)

This work was supported in part by the National Basic Research Program 973 (NO. 2010CB732606), the Guang-dong Innovation Research Team Fund for Low-cost Health-care Technologies in China, the External Cooperation Pro-gram of the Chinese Academy of Sciences (NO. GJHZ1212), the Key Lab for Health Informatics of Chinese Academy of Sciences, the Peacock Program to Attract Overseas High-Caliber Talents to Shenzhen, the National Natural Science Foundation of China (NO. 81101120, and No. 61002002). The authors would like to thank the editors and all reviewers for their careful reading of the manuscript and their valuable suggestions. The authors are grateful to Value Platforms Limited, PCCW Limited, and Novo Care Technology (Beijing) Co., Ltd. for their supports to the ITF projects.

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2) Numerical implementations

The blood is assumed to be laminar, incompressible viscous flow. Since the fluid-wall interface is moving with vessel wall, the governing equation is the NS equation incorporated with Arbitrary Lagrange Equation as:

$$\rho\frac{\partial u}{\partial t} - \nabla\cdot\left[(-p)I + \eta(\nabla u + (\nabla u)^T)\right] + \rho\left((u-\Psi)\cdot\nabla\right)u = F \qquad (1)$$

with continuity equation:

$$-\nabla\cdot u = 0 \qquad (2)$$

The vessel wall and plaque are implemented with MR strain energy function defined as:

$$W = C_1(\bar{I}_1 - 3) + C_2(\bar{I}_2 - 3) + D_1(\exp(D_2(\bar{I}_1 - 3) - 1)) \qquad (3)$$

the values of material constants follows the data from Tang et.al [4]. The wall motion curve is record by measuring the US image sequences. The maximum displacement is 0.5mm when the highest flow velocity is recorded.

III. Result

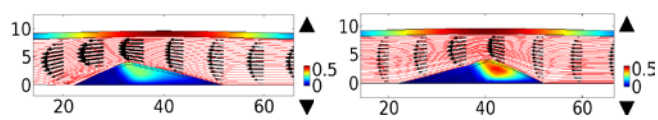

Figure 2. The hemodynamic distribution and the plaque displacement distribution at the time of the maximum velocity appeared.

Figure 2 illustrates that vortex appears in distal throat case (left), but not in the proximal case (right). Displacement of the plaque dissipates from the throat to the base of the plaque and that of proximal throat geometry is greater than distal one.

IV. Discussion and Conclusion

The flow separation is a common phenomenon in stenotic arteries. However, in our study, we found that it is not only depending on the stenosis severity, but also geometry-dependent. This implies that distal throat geometry has potentially higher risk in thrombosis when a proximal one facing greater risks in mechanically rupture.

Acknowledgment

The authors are also thankful to Doctor Li Zhenzhou from The Second People's Hospital of Shenzhen for his clinical supports.

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