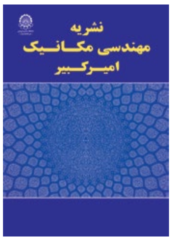

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Numerical Study of the Hemodynamic Parameters of Y-Bypass Graft at Rest and Exercise State

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ABSTRACT: The simulation of blood flow in bypass grafts can help medical evaluation. Numerical simulation of blood flow in Configurations recommended by the surgeon Such as the configurations of Y is the aim of this study in order to predict hemodynamic parameters of this configuration in a patient with double stenosis 65 and 50 percent is examined at rest and during exercise. The computational domain was created from CT images from the human cardiac. In this study, blood is assumed homogeneous, non-Newtonian and pulsatile. For real modeling of flow and blood pressure, lumped model is used in outlet at rest and exercise states.The results indicate using this configuration is compensated the pressure drop and flow and time average wall shear stress has reduced in stenosis region and oscillatory shear index and relative residence time range has reduced in area pre and post-stenosis.Y bypass grafting investigation indicates time average wall shear is low at the bifurcation graft and There is possibility of creating restenosis in these areas, but These parameters are in the ideal range at the exercise state.

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1. Introduction

Coronary Artery Disease (CAD), a type of vascular wall disease such as Intimal Hyperplasia (IH) or atherosclerosis that it could considered as a major cause of death in the world. Currently, stent placement and Coronary Artery Bypass Graft (CABG) are effective methods to treat disease of Atherosclerosis. However, up to 25% of grafts fail within one year and up to 50% fail within ten years after surgery [1]. Recently, it has been recognized that success of CABG surgery depends on hemodynamic parameters, such as rheological behavior of blood, waves of pressure and flow and distributions of wall shear stress, OSI and RRT near the stenosis coronary artery in the pre and postoperative [2,3]. Computational Fluid Dynamics (CFD) techniques are capable realistic simulation of blood flow in vascular of patients. In the era of minimally invasive surgical approaches, CFD could help surgeon preoperative. On the other hand, due to existence of difficultly and limitation in determination of the hemodynamic parameters for in-vivo and vitro experiments, CFD simulations selected as the best method to investigate this parameters. Over the last decades, numerous CFD studies have been conducted on the blood flow.

2. Boundary Condition

The motive force of the blood flow is the pressure gradient in the aorta and coronary artery. The outflow from left ventricle is not always uniform because valve of aorta is caused flow disturbance. Although an exact effect of valve of aorta cannot be exactly simulated, using pressure-inlet boundary condition we can ignore uniform inflow at inlet of aorta which has been used in previous studies [5,6]. Thus the pressure inlet boundary condition in the present study will be more realistic. The pressure pulse has been applied to inlet of aorta at the rest condition. Downstream and upstream arteries were removed from computational domain to reduce cost of calculation. Therefore, ascending of aorta, proximal of Left circumflex artery (LCX) and Right coronary artery (RCA), Left anterior descending (LAD), Diagonal1 (D_1) and Diagonal (D_2) has been selected as portion of the >5 billion blood vessels in the human circulation. Effects of downstream and upstream arteries should be considered on computational domain to model waves of pressure realistically and to simulate hemodynamic parameters accurately. It is necessary to describe the conditions at the interface of the modeled domain and the remainder of the circulation. Consequently, lumped model was applied to the outlets of the aorta and coronary artery. Using the lumped model, unlike flow in aorta, coronary flow decreases when the ventricles contract and coronary flow increases when the ventricles relax. Three-element Windkessel model and Seven-element Lumped model applied to outlets of aorta and coronary artery, respectively [7,8]. The Three-

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element circuit is composed of a resistance, capacitance and impedance and this model is solved with the three-dimensional model, as shown in Fig. 1.

3. Computational

To ensure periodic nature of the flow, the simulations were performed for three cardiac cycles (pressure pulse) where each cycle is 1 s and 0.5 s at the rest and exercise conditions, respectively. The results from three cardiac cycles are discussed in the results section. The numerical calculations were carried out using Finite Volume Method (FVM) in ANSYS FLUENT software. Temporal discretization was performed with a second order backward Euler scheme and the spatial discretization used second order central differencing. Pressure was solved through the pressure-velocity coupling method known as the SIMPLE algorithm. The residual for solution was kept at 0.00001 and the simulations progressed with a time step of 0.0025 s and 0.001 s at rest and exercise conditions, respectively. The computational mesh utilized in primary simulations consisted of nearly 1,497,801 and 2,485,123 Triangular elements for patient geometry in the pre and postoperative of graft bypass, respectively. The transient simulations were performed with personal computer with 3.6GHz Core i7 Duo processor with 16GB of RAM.

4. Equation

In this study, numerical simulation was conducted under unsteady condition. The artery walls were defined as rigid and no-slip. Blood was assumed as incompressible, laminar, non-Newtonian fluid. The motion of blood flow is governed by the continuity Eq. (1) and the momentum Eq. (2) [8].

$$u_{i,j}=0 \tag{1}$$

$$\rho(\frac{\partial u_i}{\partial t}+u_j u_{i,j})=-p_i+\tau_{ij,j} \tag{2}$$

Where u is blood velocity, is blood density and is the stress tensor which is defined by Eq. (3)

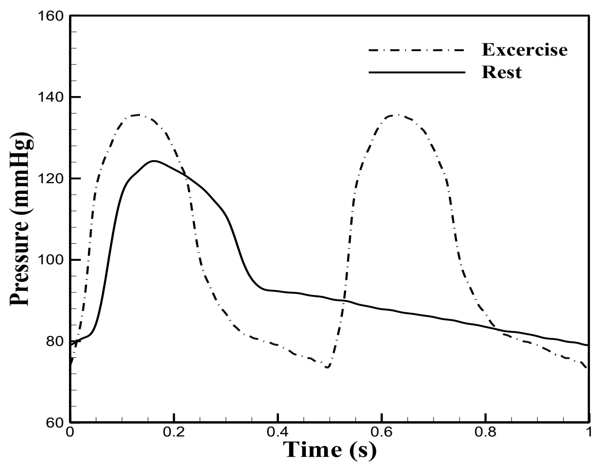

Fig. 1. The pressure pulse derived from measured data rest and exercise conditions

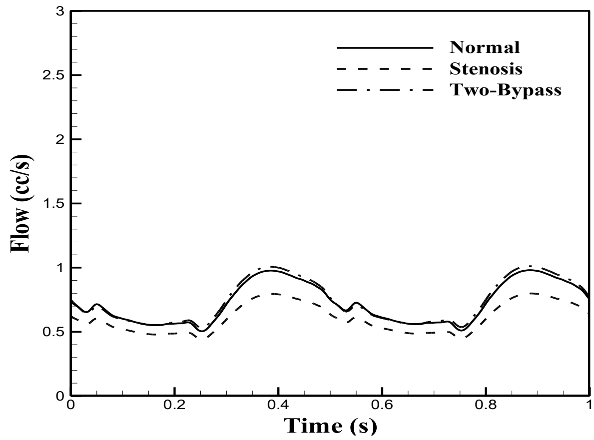

Fig. 2. Wave of flow in branches of (b) for geometry of normal, patient and with bypass

$$\tau_{ij}=\mu_{eff}\dot{\gamma}_{ij} \tag{3}$$

5. Results and Discussion

Fig. 2 shows the flow and pressure distributions among LAD and Diagonal2 (D_2) branches in the pre and postoperative of CABG under rest state, respectively. There are 65% and 50% area stenosis in the upstream and downstream LAD branch. In disease condition, maximum flow rate is 0.55 cc/s and 0.88 cc/s and maximum pressure is 80 mmHg and 81.04 mmHg in LAD and D_2 branches at diastolic phase of rest state, respectively. In compared with normal state, maximum flow has dropped 13.6% and 9.63% and maximum pressure has dropped 18.12% and 13.68% at diastolic phase of rest state, respectively. Maximum flow rate increased to 1.51 cc/s and 0.976 cc/s in LAD and D_2 branches at diastolic phase of rest state in post-operative of CABG. The results show, these drops removed when the graft connected from ascending aorta to the LAD and Digonal2 (D_2) branches.

6. Conclusion

Y bypass grafting investigation indicates time average wall shear is low at the bifurcation graft and there is possibility of creating restenosis in these areas, but these parameters are in the ideal range at the exercise state.

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