FLOW INDUCED SHEAR STRESSES IN MODELS OF STENOSED CORONARY ARTERIES

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INTRODUCTION

Heart diseases, which are induced by occluded coronary blood vessels, are the number one cause of death in the western world. There is, therefore, a great importance studying coronary flow field and its characteristics in normal and stenosed vessels. . One of the main issues is the effect of the flow field changes in partial occluded vessel on blood hemodynamics

METHODS

In order to investigate the characteristics of the flow field on blood hemodynamics, a flow system with condition, similar to blood vessel, was designed and constructed. Several stenosis models, symmetric and eccentric, Figure 1, with several area reductions and relevant elastic properties were built. These models were tested in close flow loop seeded with micron particles and derived by computerized pump, which imitated the physiologic waveform in coronary arteries. The flow in the post-stenotic area, as shown in Figure 1, was analyzed using CDPIV (Continuous Digital Particle Image Velocimetry) technique with its relevant software. In particular, the system allows for a dynamic mapping of the shear stress so the exposure of any blood particle to the shear stress can be flowed and data can be obtained. It also allows tracking down the statistical location of particle in time.

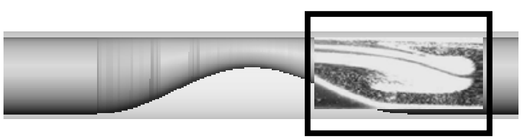

Figure 1. An example of 84% eccentric stenosed model

RESULTS

The results describe the development of two extreme flow areas: 1.jet, which produced high shear stresses in the vicinity of the wall, as depicted in Figure 1 for peak diastole and 2. recirculation zone in the vicinity of the jet that was characterized by low and negative velocities. It was observed that transition to turbulence occurred in early diastole. The fluid particles in the vicinity of the jet sucked into the jet and traveled in the shear layer till they trap in a vortex, accomplish one round and continue downstream. Figure 2 depicts a trajectory of a fluid particle that begins at the peak diastole (shown at the bottom left) in the circulation zone close to the shear layer the duration of the trajectory is 2sec and its length is 14mm. The peak gradient takes place after 22mm in the vortex. Comparison between the models showed that in the symmetric model the washout were more frequent. There were two-shear gradients in the symmetric stenosis model, as compared to the eccentric model with only one shear gradient.

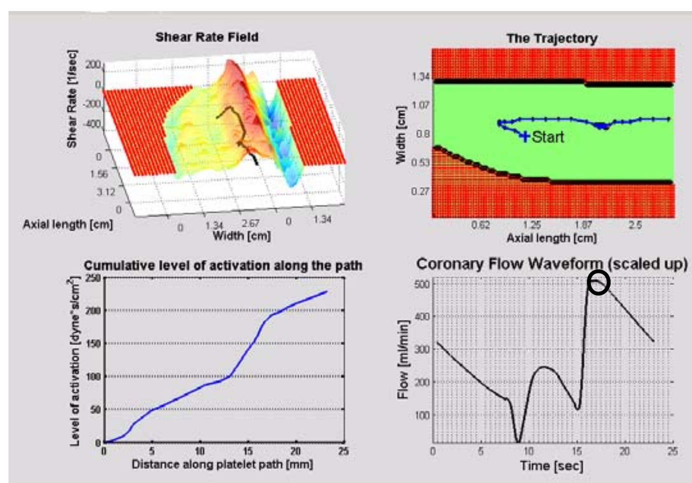

Figure 2. Trajectory starts at the peak diastole in the circulation zone.

The results of this study are of great importance to those who are working with blood hemodynamics, thrombus formation and atheriosclerosis. The activation of the hemostatic system is related to a series of rheological and hemodynamic processes. The recirculation zone that is characterized by low shear stresses and the long residence time of the moving particle, turn to be an ideal place for thrombus formation. The combination of high shear rate zone and a recirculation zone in the stenotic throat is ideal for thrombus production. The long dwelling time of a blood element in a circulating flow patterns activate the hemostatic system, and even trap the particle in the recirculation zone. The cumulative effects of the shear stress level and the exposure duration, can determine whether it is brought beyond its activation threshold (Hellums [3], criteria).

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