AN IN-VITRO STUDY OF AORTIC FLOW FIELD IN AN ASYMMETRICALLY STENOSED ASCENDING AORTA USING PARTICLE TRACKING VELOCIMETRY

Utku Gülan[1], Beat Lüthi[1], Markus Holzner[1], Alex Liberzon[2], Arkady Tsinober[2], Wolfgang Kinzelbach[1]

[1] *Institute of Environmental Engineering, ETH Zurich, Switzerland*

[2] *School of Mechanical Engineering,Tel Aviv University, Israel*

Introduction

The design of artificial heart valves is essential since red blood cell destruction and platelet deformation have been related to flow-induced stresses on a blood element [Li, 2010]. Stenosis is a stricture with the shape of an orifice in the arterial lumen. In aortic valve stenosis, the cusps of the valve become stiffer as a result of calcification and the movement of the cusps is limited which causes a reduction in valve area and considerably higher blood velocities [Clark, 1976]. Stenosis reduces the flow rate as a consequence of viscous head losses [Ku, 1997]. It also provokes turbulence and increases energy dissipation [Yap et al., 2010]. We investigate the effects of healthy and stenosed valves on the aortic flow field in-vitro to highlight the potential risk regions for hemolysis and thrombosis.

Methods

Three Dimensional Particle Tracking Velocimetry (3D-PTV) is a non-intrusive measurement technique based on imaging of flow tracers. It allows to measure the velocity field from reconstructed 3D-Lagrangian trajectories of flow tracers [Lüthi et al., 2005]. 3D-PTV is applied to an anatomically accurate silicon replica with a mechanical aortic valve (St. Jude Medical Inc., USA). A ventricular assist device is used to mimic the function of the heart. It is driven by a pneumatical pump. To imitate aortic stenosis, one of the leaflets is immobilized. The temporal resolution of the measurement is 0.14ms. Lagrangian data is reconstructed to a uniform Eulerian grid system with a voxel size of 2×2×2mm3. The voxel wise velocity accuracy of the measurement is 0.4mm/s [Gülan et al, 2012].

Results

We investigate the flow and turbulence characteristics for both healthy and pathological cases. As shown in Figure-1, the spatially averaged peak mean kinetic energy (MKE) of the stenosed case is around five times higher compared to the healthy case. In the diastolic phase, even for the lower velocity magnitudes, MKE is higher for the pathological case. Analysing the turbulent kinetic energies (TKE) shows that TKE of the pathological case is about one order of magnitude higher than the healthy case during the peak systole.

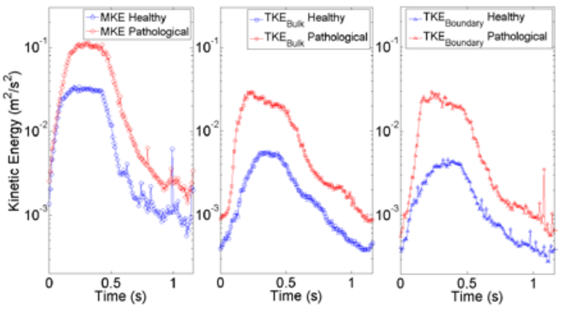

Figure 1: Temporal variation of spatially averaged mean (left) and turbulent (center, right) kinetic energy of the flow

Conclusions

We observed that flow velocities are higher for the pathological case. More coherent counter-rotating vortical structures were found in the healthy case. We show that the velocity fluctuations are higher for stenosed case as stenosis provokes more intense instabilities. In the pathological case, elevated TKE levels are found at the interface between the jet-like flow issuing from the stenosis and the ambient flow region. We conclude that the pathological case introduces more disorganized flow features as a result of high shear stress. Furthermore the regions in the vicinity of the stenosed valve are found more risky for the destruction of the red blood cells and platelet deformation.

References

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