Fluid-Structure Interaction Simulation Of The Mitral Valve In A Normal Left Ventricle During Diastolic Phase

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ABSTRACT

In this paper, the blood flow inside a normal (healthy) left ventricle was investigated, using loosely coupled fluid-structure interaction (FSI) algorithm during diastole. The model consists of the mitral valve (MV) and cavity of the left ventricle (LV) as illustrated in figure 1. Parametric geometries of the left ventricle and mitral valve were developed using MR images and pathological data. To apply pressure boundary condition to the aorta, we simulated the systematic arterial tree by characterizing the Windkessel model [1]. The Alexander model [2] was used to apply the left atrial flow to the mitral valve. The simulation started at the beginning of the systole by moving the left ventricular wall inward to push the blood flow out of the LV toward aorta. The displacement of the wall was transfered to the fluid mesh and the Navier-Stoks equations were solved using finite volume with SIMPLE-C method. We applied the calculated pressure to the surfaces of MV leaflets and the structural model of the MV tissue [3] was solved using finite element method. At the end of the cycle, we transfered the calculated deformations of the leaflets to the fluid mesh. For the next time step, the left ventricular wall was moved further and the same procedure was repeated until the end of systole. In the diastolic phase the aorta was closed and the transmitral flow was applied to the MV orifice. Also the left ventricular wall was moved backward at each time step and the same FSI cycle was used to calculate the blood flow and MV deformation in diastole. We characterized the creation of the vortex ring by the pulse jet which was produced in the early diastole. At the beginning of the diastole a vortex ring is separated from the boundary layer at the tip of the leaflets. Our study shows that no more energy contributes in the vortex ring if we increase the formation time (which describes the formation of the vortex ring) higher than 4.3 and after this point, the flow contributes in the trailing jet. We also studied the effect of the motion of the leaflets on the formation of the vortex ring and finally, we compared our results with the experimental works in which similar phenomenon was studied [4 and 5].

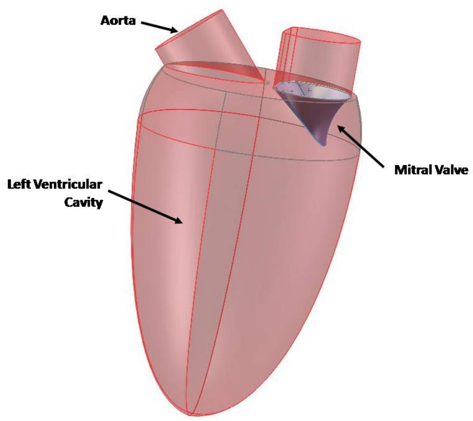

Figure 1: The computational model includes the mitral valve and cavity of the left ventricle

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