Analysis of Fluid-Structure Interaction for Left Ventricular Motion Model Using Myocardial Contractile Force

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1 Background and Purpose

There are two atriums and two ventricles on the heart, and it has the function as the pump to flow blood to lungs and the whole body by repeating constriction and dilatation. Especially, the left ventricle is an important organ because it has the role to flow out blood to the whole body. The heart is made of a lot of cardiomyocytes. The constriction of heart is caused by the calcium ion concentration rises in the cardiomyocyte by action potential. It is very difficult to measure the intracardiac blood flow caused by heartbeat. So far, there are a lot of results of the measurement that uses Magnetic Resonance Imaging (MRI), Coputed Tomography (CT), and the supersonic wave, etc. However, it is not clarified clearly.

In this research, we constructed the left ventricular motion Model that used the contractile force of the cardiomyocyte calculated from "simBio" and "Kyoto model" that Amano at Kyoto University had constructed. We analyzed of fluid-structure interaction by using the left ventricular motion model composed of left atrium (LA), left ventricle (LV) and aorta (AO). And we examined of outflow from LV to AO, inflow from LA to AO and flow in LV.

2 Construction of LV Motion Model and Fluid Area

We made the left ventricular motion model using the shell element, and connected the cylinder that imitated AO with the upper part of truncated cone that imitated LV. LA and AO are the same shape, because we don't consider the constriction of LA in this model.

We made the fluid area using the solid element, and set the left ventricular motion model in the fluid area. The fluid flows only in the inle/outlet of AO/LA. Moreover, the adjacent area at the inlet/outlet set pressure boundary.

3 Computation Method

In this research, it used LS-DYNA made of Livermore Software Technology Corporation to analyze the heartbeat of LV caused by the contractile force of the cardiomyocyte and the blood flow caused by the heartbeat. The left ventricular motion model set to lagrangian mesh, and the fluid area set to eulerian mesh. We analyzed of fluid-structure interaction for the left ventricles transformation and the blood flow by uniting the lagrangian mesh with the material point of the eulerian mesh.

The contractile force of the cardiomyocyte gives to each node of the left ventricule, direction of it set y-axially and circumference. The blood style controlled by fixing/opening the displacement of the aorta valve position in the fluid area.

4 Result and Consideration

LV contracts when the contractile force of the cardiomyocyte increases, and dilates when the contractile force of the cardiomyocyte decreases. The vortex similar to the vortex that kilner had measured occurred when LV dilatation. The outflow velocity from LV to AO and inflow velocity from LA to LV were half the velocity compared with actual measurements. But, the tendency was able to be obtained. Ejection fraction of this model was calculated by using flux to AO and the capacity of LV when maximum

dilatation. As a result, Ejection fraction was 14.5[%], and it was smaller than a normal LV value (60∼80[%]).