Opening and Closing Simulations for Tricuspid and Bicuspid Aortic Valves

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Aims: Aortic valve is located beteen the left ventricle and the aorta and has a role to convey blood with fresh oxygen and enough nutritions to the details of the body. If this valve malfuctions, surgical operations are needed. One is aortic valve replacement (AVR) and the other is aortic valvuloplasty (AVP). AVR replaces the malfuntioned valve with an aortifical one and the patients are required to take medicines to prevent thrombosis from generating. On the other hand, AVP does not require the patients to take medicine; however, it is a difficult operation for surgeons and there are varieties of valves such as tricuspid and bicuspid ones. We have been trying to simulate pressure change in the left ventricle and the aorta for a normal tricuspid aortic valve [1-3]. This paper here aims to perform the opening and closing simulations for two types of models: a tricuspid valve with long effective height and a bicuspid one.

Materials and Methods: Computational models with the left ventricle, aorta and aortic valve are generated with computer graphics modeling software called Blender and the generated surface models are translated to particle models constructed with so many small particles. Governing equations are Cauchy's equation of motion and equation of continuity, and Navier-Stokes equations and Cauchy-Navier equations are derived from Cauchy's equation of motion by applying constitutive equations of fluid and elastic body, respectively. Moving particle semi-implicit (MPS) method is employed for the simulations because blood is considered as incompressible fluid. Component names and sizes constructing the aortic model are shown in Fig. 1 and Table 1, respectively. Also, Fig. 2 (a) and (b) show the tricuspid and bicuspid aortic models generated with particles, respectively. The eH of the tricuspid model is longer than that of the bicuspid model.

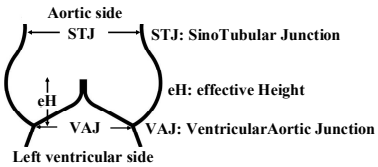

Fig. 1 Names of each component

Table 1 Component sizes constructing aortic models.

	STJ [mm]	VAJ [mm]	eH [mm]
Average size	26.6	24.2	8.5
Long tricuspid	26.0	24.0	12.0
Bicuspid	26.0	24.0	8.0

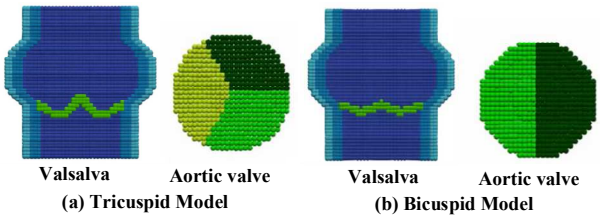

Fig. 2 Particle models for tricuspid and bicuspid valves.

Results: At first, the pressure in the left ventricle is about 0[kPa] because there is not so much blood, while the pressure in the aorta is about 9[kPa]. This time, the aortic valve closes. During the isovolumetric contraction, blood flows from the left atrium into the left ventricle so that the left ventricular pressure increases. By giving 22[kPa] as the pressure in the left ventricle, the aortic valve opens and blood flows from the left ventricle into the aorta. On the other hand, during the isovolumetric relaxation, the left ventricular pressure goes back to 0[kPa] and the reflection from the peripheral blood vessels occurs. Then, by giving 22[kPa] as the pressure in the aorta, the aortic valve closes.

Conclusions: The aortic valve opened and closed according to the simulations for the tricuspid and bicuspid models. However, the pressures in the left ventricle and the aorta are given as a constant valve and changed at once; however, the real pressures increase and decrease continuously. In addition, the root of the valve separated at the opening because each petal of the model was separately generated. In the future, we plan to solve the above issues for the precise simulations.

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References:

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