Computational Mechanical Analysis for aortic dissection in 3-layered Aortic Arch Model with Fluid-structure Interactions

Feng Gao

1 Purpose

The purpose of this research is to investigate the biomechanics of aortic dissection. Aortic dissection is a pathological state in which a tear develops in the intima layer of the aorta, the blood enters at the site of the tear, separates layers of aorta, and spreads the dissection. Defining the factors in aortic dissection may provide useful data for inclusion in the design of prevention systems. From the mechanical point of view, tear and dissection appear if the stresses acting on the wall rise above the ultimate value for the aorta wall tissue. This research aims to investigate the wall stress in aortic wall and to provide an insight for the process of aortic dissection.

2 Idea and approach

Computational cardiovascular mechanics has allowed scientists to create three-dimensional models for the simulation of cardiovascular problems. Mechanical stress plays a crucial role in the function of the cardiovascular system; stress analysis is a useful tool for understanding vascular pathophysiology. The aorta is a large-caliber vessel that consists of three distinct layers. The three-layered aortic arch model can be constructed based on the aorta structure. The interaction between flow and wall structure is simulated by loosely coupled method. The stresses along the arch portion as well as across the three-layered wall thickness can be calculated. This research uses FSI method and establish a three-layered wall structure elastic finite element model to do the simulation. The study offers a significant advancement in incorporating biomechanical principles and can provide an insight for the resultant risk of aortic dissection.

3 The progress of research

In this research, a three-dimensional aorta model was constructed based on the aortic arch shape. To deal with the pulsatile flow, a flat flow velocity
profile was used together with pulsatile waveform based on reported experimental data at the aortic inlet. The Reynolds number is fixed at Re=4000 based on the inlet velocity at peak systole of the cardiac cycle. During one cardiac cycle, the stresses in aortic arch wall are changeful, due to the time-dependent fluid flow and the arch structure. The stress at systolic acceleration phase is highest among those at four different times. Arterial stiffness is an important determinant of cardiovascular risk. The main structural alterations at the site of the large artery media account for arterial stiffening. The aortic wall stiffness as well as the medial stiffness change with age and atherosclerosis and may be an important determinant of cardiovascular risk. To investigate the effects of wall stiffness on the mechanical wall stress in a three-layered arch aortic model, the medial stiffness was varied and wall stress was computed in three-layered arch model under a blood flow.

4 Future direction

The patients with aortic aneurysm are prone to have aortic dissection. Some previous studies demonstrated distal aortic arch fusiform aneurysm in aortic dissection. To investigate influence of arch aneurysm on the wall stress, arch aneurysm will be added to the aortic model. The branches of aorta will be added to the multi-layered aortic model to investigate the effects of branches on the interaction between fluid and structure.

5 publication

Feng Gao, Masahiro Watanabe, and Teruo Matsuzawa, Loose Coupled Simulation on A 3-layered Aortic Arch Model, CCSE Workshop on Coupled Simulation and GRID Applications, Kyoto, Japan, May 2005.


