IJBSCHS(2011-17-1-11)
[Original article]
Biomedical Soft Computing and Human Sciences, Vol.17, No.1, pp.81-87

(Accepted on 2011.02.24)

Mixed Velocity-Pressure (v-p) Finite Element Method in Assessing the Hemodynamic Wall Shear Stresses in a Fusiform Abdominal Aortic Aneurysm

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Abstract: *In this paper, a mixed velocity (v-p) finite element method was used to analyze pulsating blood flow-induced wall shear stress (WSS) in an idealized fusiform abdominal aortic aneurysm (AAA). A three-dimensional mathematical model of the axially symmetric AAA was introduced. The Navier-Stokes and the continuity equations were solved numerically by exploiting the Galerkin method and the fully implicit incremental-iterative procedure. A physiologically realistic pulsatile blood flow waveform was imposed onto the AAA model. This pulsatile condition simulates an in vivo aorta at rest. The developed finite element technique may proof to be useful for biomedical engineers who aim to develop specialized software simulation packages. Computational modeling is becoming a powerful tool in today's medical treatment planning and predictive methods. Today, clinical application of numerical modeling and computer-aided surgical planning is considered the key for the future of medicine.*

Keywords *Three-dimensional finite element method; Pulsatile flow; Fusiform abdominal aortic aneurysm; Wall shear stress (WSS).*

1. Introduction

Abdominal aortic aneurysm (AAA) is a dilatation of the infrarenal abdominal aorta that lies between the renal bifurcation and the iliac branches. The main causes of aneurysm are arteriosclerosis and cystic medial degeneration. Genetic disorder, malfunction of the aorta (i.e. biomechanical phenomenon), mycotic infections or arthritis can also be a cause of AAAs[1]. Another cause of aneurismal disorders mentioned by scientists is the loss of distensibility of the vessels. Loss of distensibility or increased stiffness of the vessel wall is due to the loss of elastin and increase in collagen content in the aortic wall. This loss is a general result of aging.

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This pathologic condition has been found to affect 8.8% of the population over the age of 65 and if left untreated it may lead to rupture[2]. The size of the aneurysm and its rate of expansion are parameters widely associated with the risk of rupture[3]. The decision for surgical intervention for patients with AAAs is complicated because of the lack of a sufficiently accurate rupture risk index. Based on the results from a number of clinical studies, the maximum/peak transverse diameter (PTD) is widely used[4,5,6,7]. In cases where PTD exceeds 5 cm – 6 cm, surgical or endovascular treatment is advised.

We believe that it is important to look into the biomechanical aspects of AAA disease development such as the flow-induced wall shear stress that acts on the AAA walls rather than just the size of the AAA. Of course, it is quite difficult to experimentally measure the flow-induced wall shear stress experienced by the AAA walls. In view of this, it would be easier to develop a computational technique that calculates the wall shear stress directly from the blood flow.