Wall Shear Stress for an Aorta with Aneurysms via Fluid-Structure Analysis

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Abstract. Aortic aneurysms have become one of the most common life-threatening aortic diseases diagnosed with severe consequences including aortic dissection. Three-dimensional fluid-structure model is developed to simulate the nonlinear behaviour of an aorta with aortic aneurysms for the prediction of wall shear stress as one of the leading causes for dissection. The simulations of the theoretical fluid-structure interaction (FSI) are built using the Finite Element Method (FEM) with consideration of the following parameters: pulsatile non-Newtonian blood flow, aneurysm size and shape, and varying mechanical properties of different aortic wall layers. Incorporating all these factors in the simulation model is critical for the reliability and accuracy of the results. Influences in rupture predictions due to these parameters are discussed, and the generated model can numerically provide weak regions of the aorta with low wall strength or experiencing higher stress, which identifies the high risk for dissection. The biomechanical model introduced in this paper could be utilised to estimate the connection between aortic aneurysms and the risk of aortic dissection.

Introduction

The aortic aneurysm is considered as the most common aortic diseases diagnosed with high risks. As an abnormal condition of aorta dilation, one of the fatal consequences of aortic aneurysm is aortic dissection, which is considered as unpredictable and generally unrecoverable [1]. Dissections related to aortic aneurysms usually associated with the mechanical property changes in the aortic wall and the initial estimation of the aneurysm condition is thus critical for dissection prediction in both research and medical practice fields [2]. Figure 1 shows a Gadolinium-enhanced MRI image of an abdominal aortic aneurysm. The fluid-structure analysis allows examinations on wall shear stress numerically in order to investigate nonlinear dynamics and changes in the mechanical properties of the aortic wall caused by aortic aneurysms [3]. This technique has been employed in some other vascular diseases, including peripheral artery disease and coronary artery disease [4]. To prevent the dissection in the aorta and understand the influence of different parameters, a biomechanical model is developed to determine the wall shear stress distribution as one of the main factors in dissection.

Figure 1: MRI of an abdominal aortic aneurysm showing tortuous aorta and iliac arteries [5]

Results and Discussion

An aortic dissection could occur due to the following reasons: material property failure of the intima layer on the aneurysm, changes in blood flow caused by geometry variation associated with aneurysm [6]. In order to compare the effect of aneurysm shape and blood pulsation, an index to analyse the wall shear stress field is calculated for aortic aneurysm by developing a finite element model in ANSYS. Conclusions can be drawn from the stress concentration investigation as maximum wall shear stress occurs when pulsation reaches its maximum velocity and the stress concentration changes significantly with the size of aneurysms.

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