INFLUENCE OF WALL THICKNESS AND MATERIAL PROPERTIES ON ANEURYSM DEVELOPMENT: A FINITE ELEMENT STUDY

Andrea Bucchi[1], Gianluca Tozzi[1], Jie Tong[1], Grant E. Hearn[2]

[1] *School of Engineering – University of Portsmouth, United Kingdom*

[2] *Fluid Structure Interaction Research Group – Faculty of Engineering and the Environment – University of Southampton, United Kingdom*

Introduction

Different types of aneurysm can develop in the human body. In the case of an abdominal aortic aneurysm (AAA) the risk of mortality associated with rupture is in the range of 65-85% [Sakalihasan et al., 2005]. Most of the research reported in the open literature is focusing on the risk of rupture in fully developed aneurysms [Raghavan et al., 2000]. Moreover, in the numerical simulations the aneurysm geometry is artificially generated with a Gaussian (or similar) bell-shaped distribution. Typically a uniform wall thickness is adopted and the geometry is then superimposed on the healthy aorta [Rodriguez et al., 2008]. In this work the aneurysm shape is instigated as result of an elastic instability and the wall thickness variation is automatically taken into account. Furthermore, after the aneurysm formation, the tissue properties are changed from the healthy to aneurytic.

Methods

The aneurysm formation is analysed via finite element (FE) model using an arc-length method [Bucchi et al., 2013]. A simple cylindrical geometry was adopted (L=140 mm, Di=18 mm, De=22 mm and constant wall thickness=2mm. After the aneurysm is formed, different shapes are tested in a subsequent nonlinear static analysis imposing a constant uniform pressure of 16 kPa (120 mm Hg). The material data used are representative of the healthy human abdominal aorta, to study the aneurysm formation, and of the damaged aorta to analyse the aneurysm growth [Raghavan et al., 1996].

Results

Figure 1 shows the approach used in the current work. Starting from a healthy aorta with a constant 2mm wall thickness (Fig.1 A), and then going towards the aneurysm formation (Fig.1 B,C). The stress level corresponding to the minimum initial thickness (0.64 mm for Fig. 1B and 0.36 mm for 1C), is shown in Fig. 1D and 1E respectively. In the first case the maximum true stress (0.75 MPa) is below the ultimate stress (0.97 MPa [Raghavan et al. 1996]). In the second case the maximum stress (1.4 MPa) represents a rupture of the aneurysm.

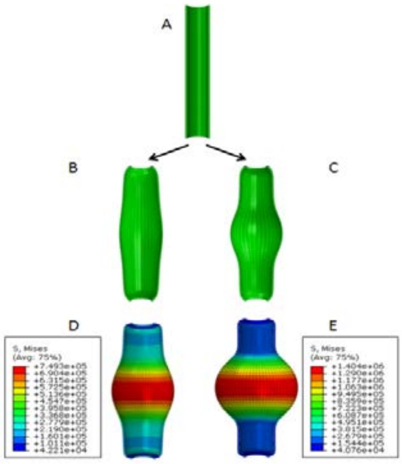

Fig. 1: FE models and relative stress distribution.

Discussion

The more realistic use of a variable wall thickness creates a wider range of stress distribution compared to previous studies where the predicted stress was far away from aneurysm rupture [Raghavan et al., 2000]. The von Mises stress is selected in accordance with [Rodriguez et al., 2008].

References

Bucchi A. et al., J Mech Sciences, (in review), 2013.

Raghavan M.L. et al., Ann of Biomed Eng, 24:573–582, 1996.

Raghvan M.L. et al, J Biomech, 33:475–482, 2000.

Rodriguez J.F. et al., J Biomech Eng, 130:021023-1–021023-10, 2008.

Sakalihasan N. et al., Lancet, 365:1577–1589, 2005.