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BIOMECHANICAL FACTORS INFLUENCING PATIENT-SPECIFIC FSI SIMULATION OF CEREBRAL ANEURYSMS

*** Ryo Torii[1], Marie Oshima[2], Toshio Kobayashi[3], Kiyoshi Takagi[2,4] and Tayfun E. Tezduyar[5]**

[1] Department of Chemical Engineering,
Imperial College London
South Kensington Campus,
London, SW7 2AZ, UK
r.torii@imperial.ac.uk

[2] Institute of Industrial Science, The University of Tokyo
4-6-1 Komaba, Meguro,
Tokyo, 153-8505, Japan

[3] Japan Automobile
Research Institute
2530 Karima, Tsukuba,
Ibaraki, 305-0822, Japan

[4] Department of Neurosurgery,
Fujita Health University
1-98 Dengakugakubo, Kutsukake,
Toyoake, Aichi, 470-1192, Japan

[5] Mechanical Engineering,
Rice University – MS 321
6100 Main Street, Houston,
77005, USA

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ABSTRACT

Because cerebral aneurysm is linked to hemodynamics [1], understanding the blood flow patterns in and around an aneurysm is important in investigating its pathological development. Patient-specific fluid–structure interaction (FSI) analysis has been a powerful tool in modeling hemodynamics in aneurysms, owing to recent developments in medical imaging and image processing techniques, computing power, and computational methods [2]. With patient-specific aneurysms reconstructed from CT images, we investigate how the biomechanical factors can potentially influence the FSI patterns in cerebral aneurysms and the resulting hemodynamics.

Hypertension is one of the biomechanical factors influencing FSI patterns in an aneurysm. It was shown that hypertension significantly changes the diameter of the neck of an aneurysm, causing more blood flow into the aneurysm [3]. High blood flow results in higher wall shear stress (WSS), which prevents the aneurysmal wall from degrading. However, the effect of hypertension highly depends on the aneurysm shape [3]. For an aneurysm at a bifurcated vessel, such as the middle cerebral aneurysm, impact of blood stream onto the bifurcation plays a crucial role. The flow impingement and resulting high WSS region is sensitive to deformation of the arterial wall, which highly depends on the aneurysm shape and blood pressure. All these findings emphasize the importance of patient-specific simulations in understanding hemodynamics in aneurysms. The impact of the wall constitutive model has also been investigated [4]. Aneurysm models with linearly-elastic and hyperelastic materials show similar displacement patterns around the aneurysm but the displacement magnitude is higher for the linearly-elastic material. Consequently, the aneurysm with the two wall models show similar FSI patterns.

In this presentation, the effects of the aneurysmal wall thickness are also investigated because the wall thickness for a ruptured aneurysm is known to be very small, approximately 0.05 mm according to autopsy reports [5]. Structural mechanics simulations of a ruptured aneurysm have been carried out with uniform wall thickness (= 0.3 mm [6]) and variable wall thickness, where the wall thickness varies from normal (= 0.3 mm) to pathological (= 0.05 mm) on the aneurysm, and the results are compared. A hyperelastic constitutive model is used for the arterial wall. Figure 1 shows the displacement patterns for the two cases exposed to systolic-diastolic pressure difference (= 40 mm Hg). The maximum displacement is 33% larger for the pathological wall thickness case. It is also notable that the pathological wall thickness model exhibits larger displacement around the aneurysm but smaller displacement at the arterial walls than the uniform wall thickness model does. The results suggest that using pathological wall thickness for aneurysmal wall reinforces the importance of FSI in modeling of cerebral aneurysms.

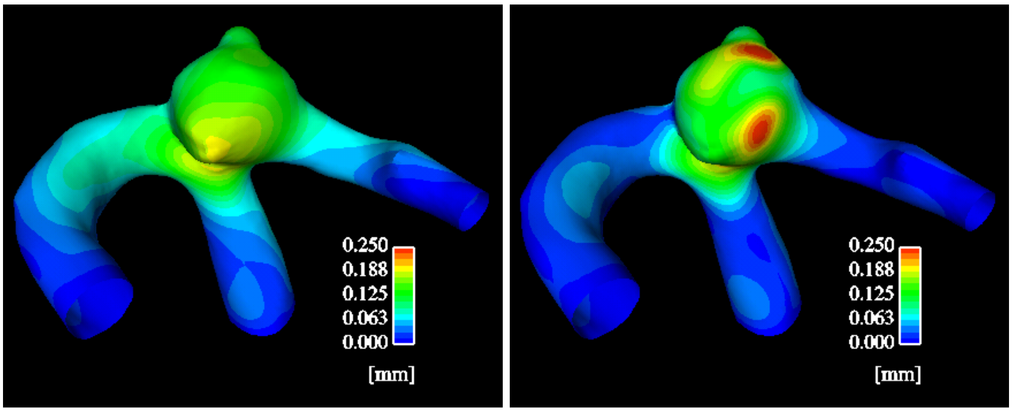

Figure 1: Displacement pattern of a ruptured aneurysm exposed to systolic-diastolic pressure difference (40 mm Hg) for uniform wall thickness (left) and pathological wall thickness (right). The thickness of the arterial wall is 0.3 mm and aneurysm wall thickness for pathological wall model is 0.05 mm.

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