PATIENT SPECIFIC NUMERICAL STUDY OF AN INTRACRANIAL ANEURYSM MECHANICAL CHARACTERISATION DEVICE

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Introduction

Intracranial aneurysm is a life-threatening pathology related to the local weakening of the arterial wall. However, there is currently no method enabling to predict the breaking risk based on *in vivo* mechanical data. This work is part of a large-scale project that aims at providing clinicians with a non-invasive patient-specific decision support tool, based on both the *in vivo* mechanical characterisation of the aneurysm wall and machine learning analyses. The mechanical properties estimation of the unruptured intracranial aneurysm wall will be obtained from a deformation device coupled with a medical imaging system. The deformed anatomical image will be numerically treated to quantify the aneurysm wall stress state by finite element inverse analysis based on the luminal volume variation.

This study aims at identifying and proving an observable aneurysm deformation induced by the device through patient specific numerical models. As the practitioner will never be able to precisely situate the device, several locations were considered. Prior to the inverse analysis procedure, increasing complexity artery models were studied (linear elastic, hyper elastic).

Methods

A patient specific Fluid-Structure Interaction (FSI) finite element model was developed on COMSOL Multiphysics. The device was designed as a guidance flux system. A single laminar flow included the pulsated flow (physiological liquid) and the artery blood flow: fluids were considered as miscible with respective inlet boundary conditions. A 1.5 s heart frequency pulsatile flow rate was applied at the artery inlet with the associated pulsatile pressure at the outlet [1]. A 0.8 s pulsatile flow was considered for the device to overlay the cardiac cycle systole. Flow rates of 150 mL/min (D1) and 190 mL/min (D2) were considered at the device inlet. A 10 mmHg intracranial pressure was applied on the artery outer wall [2].

For each device flow rate, a homogeneous model of the artery/aneurysm and a heterogeneous model depicting the local mechanical weakening of the aneurysm were considered. It was done with a linear elastic model (HOM1 and HET1) [3,4] and a Fung hyper elastic model (HOM2 and HET2) [2,3]. For each case, 5 device locations were studied: 60 artery models were built. The FSI was computed using the arbitrary Lagragian-Eulerian technique (ALE). The wall displacement norm (μm) and the aneurysm luminal volume variation (mm^3 and %) were analysed.

Results and discussion

Considering all the device locations and materials, the displacement induced by the device was between 300 µm and 1.2 mm in addition to the systole peak (figure 1). The luminal volume variation was between 1 % and 4.4 % compared to the initial systole volume (figure 2).

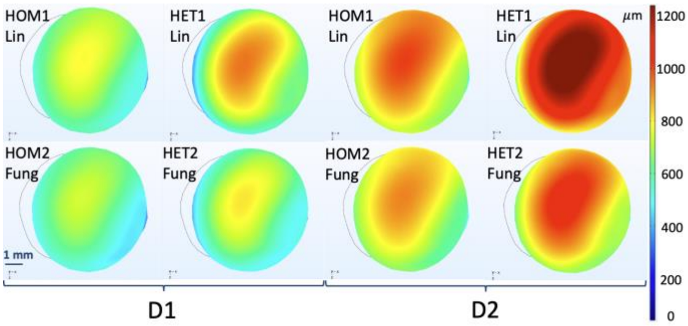

Figure 1: Additional displacement (µm) to the systole peak for a fixed device location with D1 and D2 solicitation flow rates.

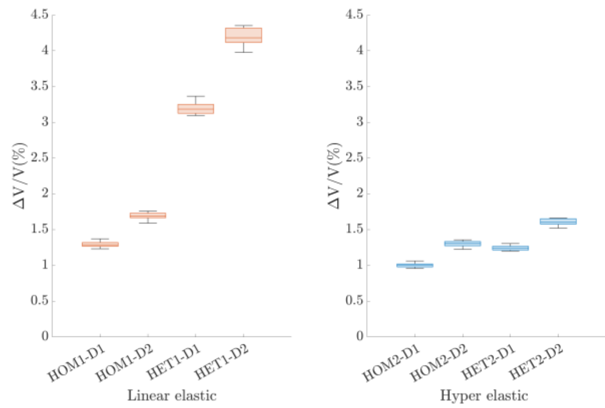

Figure 2: Aneurysm luminal volume variation (%) regarding the device location, flow rate and the artery model.

For further animal model studies, the Spectral Photon CT Counting has been chosen as clinical imaging technique, with a spatial associated resolution around 200 µm [5]. Based on this preliminary study, the displacements and associated volume variations (inverse analyses baseline), should be observable and exploitable during in vivo testing on small animals.

References

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