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COMPUTATIONAL PREDICTION OF ABDOMINAL AORTIC ENDOGRAFTING

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1. INTRODUCTION

Endovascular aneurysm repair (EVAR) is a widely used technique to treat abdominal aortic aneurysms (AAAs). Most of EVAR complications requiring secondary interventions may be related to mechanical origins [1].

Computational modeling of stents in arteries has been the object of intense research [2]. However, computational modeling of stent-graft (SG) remains rare [3, 4]. Furthermore, most of the published studies did not consider patient-specific AAA geometries.

Within this context, the goal of the present study is to develop a computational model able to predict the positioning of a bifurcated SG inside a patient-specific AAA.

2. METHODS

Surgery-oriented Endosize® software (Therenva, France) was used for the segmentation of the aneurysmal abdominal aorta and iliac arteries from the pre-operative CT scan of a given patient. The segmented geometries were then meshed using 3-node shell finite elements. The stent-graft used to treat this patient was modeled as a multi-component structure including the textile graft and metallic stents, considering the sewing between them as a perfect kinematical tie. The graft and stent geometries were respectively meshed with 4-node shell and 2-node beam finite elements.

The nonlinear constitutive equations of the arteries were linearized for the small strains induced by the SG deployment: an orthotropic linear elastic behavior was considered with 4.0 and 2.0 MPa circumferential and longitudinal elastic moduli, and 1.0 MPa shear modulus. The Nitinol material for the stents was modeled as superelastic using the properties provided by the manufacturer. The textile was modeled as an orthotropic linear elastic shell using the properties characterized in [5].

To speed up the computation of the SG positioning, the actual deployment procedure was simplified in two steps. In a first step, the SG was constrained to fit inside the geometry of the artery by prescribing appropriate displacements to all the nodes of a virtual shell surrounding the SG (see the deformation from Fig. 1(a) to 1(b)). In a second step, the previous kinematical constraints were relaxed by assigning elastic properties to the artery and by solving the mechanical equilibrium between the artery and the SG. This yielded the computational prediction of the SG deployed in the actual artery (Fig. 1(c)).

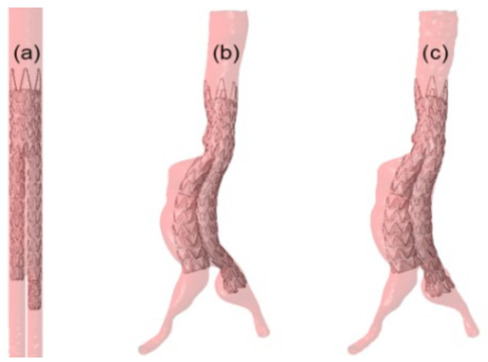

Fig. 1. Initial configuration (a), result of morphing onto the arterial geometry (step 1) (b) and final mechanical equilibrium (step 2) (c)

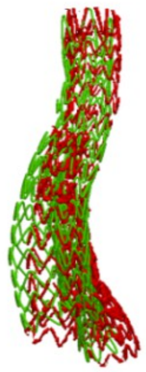

Fig. 2. Comparison of computed SG geometry (green) to the actual SG geometry (red) obtained from post-operative CT-scan

3. RESULTS AND DISCUSSION

Figure 1 presents the initial geometry, the results of step 1 (SG in the patient's arterial geometry) and step 2 (mechanical equilibrium). Figure 2 shows a comparison between the simulated final geometry of the SG and the actual geometry segmented from post-operative CT-scan images. Some discrepancies can be noticed in iliac portions, which are likely due to inaccurate boundary conditions in this region. The overlap between the limbs and the SG main body may also be slightly different between the model and the reality. Validation of the approach on a set of several cases is now on-going. The results reported here constitute the first step towards predictive simulations of EVAR. Eventually, FE simulations could become an important tool for patient and SG selection in endovascular repair.

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