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NUMERICAL DETERMINATION OF AN ANATOMICAL STRUCTURE'S UNLOADED STATE FROM IN VIVO MEDICAL IMAGING

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Context

 Implantable Medical Device (IMD) deployment's computation in patient specific anatomical structures. •Competitive computation time.

<u>Application to in vivo neural aneurysms</u>

Hypothesis:

- Soft hyperelastic material from in vivo aneurysm wall³
- Homogeneous blood pressure⁴ P_i
- No displacement on contours of the artery

<u>Objectives</u>

Inspect impact of the choice of stress-free configuration of anatomical structures in the result of IMD-anatomical structure interaction's computation.

Shell modelling

Stress-free configuration determination algorithm already exist in the litterature^{1,2}, but are adapted to volumic mesh modelization of structure.

Medical imaging, with segmentaton, provides geometrical inputs of anatomical structures as their median surfaces. To avoid a step of volumic reconstruction and thickness discretization that would results in more degree of freedom and longer computation time, one could model those structures with shells.

Our contribution is to adapt such algorithm to shell modelling.



 discretized in thickness • 3 dofs per nodes: displacements Pressurized geometries Convergence graphs from medical imaging $\|\mathbf{X}_{m} - \mathbf{X}_{k}\|_{2}$



Depressurized geometry obtained with the algorithm (pressurized in red, depressurized in blue)







Bifurcation two

lobes aneurysm



 10^{-2}

 10^{-5}

No convergence could due to flawed boundary conditions. Contact with a bone structure



should be taken into account

residual

residual

iterations

ophtalmic artery

near the



No convergence, could due to too soft material mixed with curvature, causing too big rotations.

> High curvature happens to be in the same zone than instabilities of the algorithm

With a stiffer material, the algorithm now converge



This algorithm allows to find stress-free configuration to implement computations with based of hyperelastic model and patient specific geometry. The convergence of such algorithm depends of the compatibility between the measured geometry, the boundary conditions and the assumed material of the structure.

Flowchart of the proposed algorithm

• Implement more complex boundary conditions, heterogeneous loading or contact with other structures, to adress more cases. Assign a different material to the arterial wall than the aneurysm. • Use Aitken type relaxation to improve convergence.

¹Bols *et al.* A computational method to assess the in vivo stresses and unloaded configuration of patient-specific

²Raghavan et al. Non-Invasive Determination of Zero-Pressure Geometry of Arterial Aneurysms. 2006 ³Costalat *et al.* Soft hyperelastic material from Biomechanical wall properties of human intracranial aneurysms resected following surgical clipping. 2011

⁴Steiner et al. Imposed homegeneous pressure, with values obtained from Monitoring the injured brain: ICP and LABORATOIRE DE MÉCANIQUE ET GÉNIE CIVIL - UM/CNRS CBF. 2006



