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Relationship between cerebral aneurysm wall stiffness and rupture risk

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KEYWORDS Cerebral aneurysm; stiffness; rupture; mechanical identification

1. Introduction

Haemorrhage stroke is a major issue for public health care. The prevalence of intracranial aneurysms in the general population ranges between 3 and 6.6\% (Wardlaw and White 2000). Fortunately, very few aneurysms rupture. The incidence of ruptured aneurysms is approximately 0.5\% per year. However, patients are stressful and want to be treated. But, endovascular treatment of unruptured aneurysms, which is the safest treatment, is not without risk and has about 1\% mortality rate (Sluzewski et al. 2001). So, unruptured intracranial aneurysms represent a dilemma for the physicians.

In 2011 (Costalat et al.), we have proposed an indicator base on the relationship between the mechanical properties of wall aneurysm tissues and the rupture risk. First conclusions suggested that the softer tissue is, the higher rupture risk is.

The present study aims to confirm these results, initiates with only 16 samples, studying 26 more aneurysms.

2. Methods

2.1. Patients and clinical data

A total of sixty-three patients treated for ruptured or unruptured aneurysms by surgical clipping were recruited by four French neurosurgical teams. The research study protocol was approved by the local ethical committee in each center. A consent form was signed by patients with normal neurological status, or by the relatives in all other cases. For each patient, clinical, and radiological information was collected concerning age, gender, aneurysm status (ruptured/unruptured) … All documented risk factors were recorded in order to be related to the biomechanical behavior of each aneurysm.

2.2. Biomechanical testing methodology

Immediately after resection, each aneurysm wall was progressively frozen at \(-80^\circ\text{C}\). One hour before mechanical testing, aneurysm samples were thawed at ambient temperature. Then a regular rectangular piece was dissected from the aneurysm preserving maximum length. This was a delicate point due to the small size of the samples. Many of them were lost during this cutting.

Once cut, uniaxial stretch tests were carried out on the sample within a warmed (37 \textdegree\text{C}) physiological liquid in order to simulate \textit{in vivo} conditions. This testing device was composed of a Texture Analyzer (TA-XT2, Stable Microsystems, UK) with a 50 N load cell. Aneurysm strips were fixed by glue on each extremity to aluminium grips.

The uniaxial stretch tests consisted of a series of increasing load steps until rupture of the sample (see Figure 1). For each load step the sample was stretched then unloaded and that was repeated five times. The extension rate was small enough to not consider viscous phenomena (0.01 mm/s). A baseline tension of 0 N was applied to the strip before starting each test.

2.3. Data post-processing: mechanical parameter identifications

Only the measurements from the last elongation of load step 1 were used to obtain more realistic mechanical characterization of the data, in the range of physiological solicitations. Using the assumption that the specimen was subjected to a uniform traction, the engineering stress, noted \(\Pi\), was computed, and the engineering strain, noted \(\varepsilon\), registered. Once the strain/stress graph was obtained, we proceeded to a curve fitting using a Sequential Least Squares Programming algorithm in order to determine the corresponding hyperelastic model and its coefficients. In our cases, the best match was obtained with an incompressible
the function Π(λ) identified.

You can find a hyperelastic model, an average value of parameters Young’s modulus E in treating the unruptured aneurysms having a C

and intermediate tissues had a risk of rupture, because we found a ruptured aneurysm with a C

than 3.7 MPa (soft tissues). In a general manner, both soft and intermediate tissues from males seem not to be stiffer than those of females and vice versa.

Almost certainly the physicians did the good choice in treating the unruptured aneurysms having a C

Because of the surgical resection, only aneurysms easily and safely accessible were selected, introducing a potential selection bias. Uni-axial strain/stress testing is not representative of the anisotropic behavior of the aneurysm wall in vivo, but the small size of the strips was a limitation to perform bi-axial tests. The taking of measures, such as thickness and the width, was difficult to carried out because samples were relatively irregular. So, we took average values, what can skew the estimation of C

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But, contrary to what we observed in the previous study (Costalat et al. 2011), including only 16 samples, gender has no influence on material parameters. Aneurysmal tissues from males seem not to be stiffer than those of females and vice versa.

### References


