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Non-linear Viscoelastic Behavior of Abdominal Aortic Aneurysm Thrombus

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Introduction

Abdominal Aortic Aneurysm (AAA) wall stresses, which might be an important indicator for rupture risk, can be studied using a patient specific stress analysis model of the aneurysm [1]. It had been suggested that intraluminal thrombus decreases the maximal peak stresses that occur. An ideal model for calculating wall stresses would include loading with a dynamic pressure and applying a proper constitutive model that also incorporates the viscoelastic properties of the thrombus.

The objective of this work was to determine the linear and non-linear viscoelastic behavior of abdominal aortic aneurysm thrombus and to study the changes in mechanical properties throughout the thickness of the thrombus.

Materials & Methods

Stacks of slices are gathered from the thickest part of thrombus of 7 patients (Fig. 1). Linear viscoelastic data from oscillatory shear experiments with a strain of 3% and frequencies of 0.1-10 rad/s were performed. Variations in $G'$ and $G''$ were studied within and between thrombi.

To study the non-linear regime, stress relaxation experiments with strains up to 20% are performed (Fig. 2a). To describe the phenomena observed experimentally, a non-linear multi mode model was used (Fig. 2b). The elements of the viscoelastic modes, $G_1$ through $G_n$ were chosen to be linear, whereas a nonlinear equilibrium mode $G_0$ was used.

Results

Linear viscoelastic data from oscillatory shear experiments show that the change of properties throughout the thrombus is different for each thrombus (Fig. 3a). Furthermore the variations found within one thrombus are of the same order of magnitude as the variation between patients (Fig 3b). The parameters for the model proposed were obtained by fitting this model successfully to the experimental results in both the linear and non-linear regime (Fig. 4).

Discussion & Conclusion

The model can not only describe the average stress response for all thrombus samples but also the highest and lowest stress responses. These may play an important role in rupture risk prediction using finite element stress analyses.

References: