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Including Residual Stress and Initial Strain in an Asymmetric Model of the Aortic Root

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The aortic root is the group of structures that make up the aortic valve. Besides the aortic leaflets, the aortic root complex includes the aortic annulus, the Valsalva sinuses, and the sinotubolar junction [1]. This group of structures has the functional role of assisting valve opening and closure by creating and maintaining the optimal pressure difference between the aorta and the left ventricle. To create models that can simulate aortic root function and behavior, it is important to map the initial stress distribution of the ascending aorta and the sinuses [2]. The initial stress distribution in the aortic sinuses and the aortic wall depends on the physiological loading corresponding to the diastolic aortic pressure, and on the residual stress present in the unloaded state. While the unloaded state, i.e. the state in which the diastolic pressure loading is removed, can be estimated by solving the inverse elastostatic problem, the residual stress is usually taken into account by performing opening angle experiments on the arterial wall [2].

In the present work, we aim at estimating the initial stress distribution in a symmetric and asymmetric aortic root geometry, see Figure 1 (a)-(b). The aortic root geometry is based on data of Swanson and Clark [3], and is modified to account for the physiological asymmetry of the sinuses [1]. The aortic root is modeled as an incompressible, hyperelastic material using a strain energy functional fit to biaxial tensile test data [4]. To compute the initial stress distribution in the aortic root, we consider the diastolic aortic loading and the residual stress separately, and we solve the inverse elastostatic problem by using the backward displacement method proposed by Bols et al. [5]. To include an estimate of the residual stress, we propose an elaboration of the iterative routine proposed by Alastruè et al. [6].

Preliminary results of the implementation of the backward displacement method are shown in Figure 1 (c)-(d), which shows the distribution of the Von Mises stress in the aortic root. Although the distribution across the aortic thickness is similar in the two geometries, the asymmetric geometry presents higher stress at the apex of the left sinus.

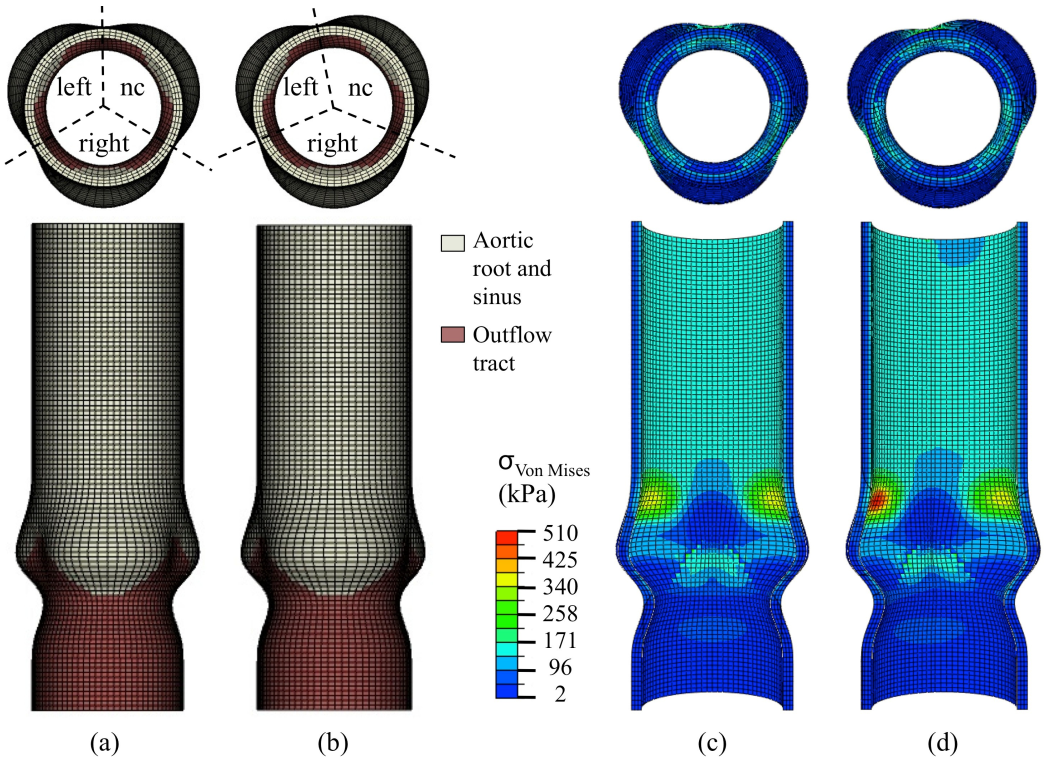

Figure 1: Symmetric (a) and asymmetric (b) model of the aortic root, nc indicates the non-coronary sinus; stress distribution due to the diastolic loading of the aorta in the symmetric (c) and asymmetric (d) model of the aortic root.

Future work includes validation of the residual stresses by comparisons to opening angle tests, and the use of this model in dynamic fluid-structure interaction simulations.

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