Residual stresses resulting from growth and remodeling in arterial walls

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ABSTRACT

Being exposed to changes in its mechanobiological environment, arterial tissue continuously strive to optimize its load-bearing capacities by adapting to these altering conditions. This optimization procedure is characterized by growth and remodeling processes which are supposed to be the source of residual stresses in externally load-free states. These residual stresses have to be accounted for in numerical simulations, see e.g., [1, 5, 3], since they reduce stress magnitudes and gradients in loaded states. Constitutive equations for soft biological tissues commonly describe the anisotropic material behavior by modeling the tissue as an isotropic matrix material with embedded fibers. Based thereon, the reorientation of fiber directions and the addition of supplementary material can be considered to model adaptation processes and to quantify the associated residual stresses. For both mechanisms, the intensity and the direction of principal stresses are supposed to be of particular importance. It is assumed that the two fiber families in arterial walls are aligned symmetrically with respect to the tensile principal stresses, which are expected to be mainly located in the plane of the vessel wall. Following this assumption, a combined framework of anisotropic growth and fiber remodeling is proposed. The growth model is based on the multiplicative decomposition of the deformation gradient into a growth tensor and a remaining elastic part, see e.g., [4]. Instead of using fixed structural directions to incorporate the anisotropy of the growth mechanism as done in existing approaches, the growth tensor itself is decomposed into two parts related to the directions of the highest (tensile) principal stresses. A rearrangement of the fibers as proposed in [2] is then expected to have twofold effects: an advantageous redistribution of the stresses and a direct effect on the growth directions, which are automatically adapted such that a reduction of high principal stresses is promoted. Numerical examples on idealized arterial segments, illustrating stress and fiber angle distributions as well as residual stresses, are presented.

REFERENCES