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A FINITE ELEMENT IMPLEMENTATION OF GROWTH AND REMODELING BASED ON THE HOMEGENIZED CONSTRAINED MIXTURE MODEL

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Summary: Experimental observations suggest that arterial growth occurs anisotropic and most likely in thickness direction of the arterial wall. It may be because anisotropic growth can more effectively provide the stability of blood vessels under perturbations [1]. Recently growth and remodeling (G&R) has been increasingly modeled based on constrained mixture theorem (CMT) to predict a variety of arterial behavior [1, 2]. Mostly previously published work has been limited to simplified cases as isotropic growth, axisymmetric motions, mono-layer wall and/or membrane approximations. Therefore, a 3D anisotropic bilayer model has the potential to consider more realistic cases. Thus, herein, a 3D numerical model based on homogenized CMT is implemented in ABAQUS through a coupled UEL to predict anisotropic G&R of arteries. At the Gauss points level, the passive behavior is assumed hyperelastic and a strain energy function (SEF) is assumed for each constituent with decoupled contributions of the purely volumetric and isochoric parts. Although the same SEF is assumed for every element across the geometry of the artery, different material properties and mass fraction can be applied at each layer. It is considered that the arterial wall is composed of a constrained mixture of elastin, collagen fibers and smooth muscle cells and includes the in situ stresses existing in the reference configuration. Four collagen fibers with different mass fractions in media and adventitia in the axial, circumferential and angular directions are considered. The contractility and growth of the muscle and turnover of collagen fibers are assumed stress dependent. To show application of the model, simulations were performed on a bilayer thick-wall tube subjected to different boundary conditions in homeostatic conditions, as in the ascending thoracic aortic aneurysm (ATAA). Different rates of elastin degradations and gain parameters of collagen fibers are consider. As realized in the case of aneurysms leading to rupture, the model was able to predict unbounded increase of the tube diameter and the wall stress. Our findings indicate the determinant role of collagen mass deposition during thickening of arterial wall. The implemented numerical model can be considered as an appropriate alternative to study anisotropic growth and remodeling in the vasculature.