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Stress Softening and Permanent Deformation in Human Aortas: Continuum and Computational Modeling with Application to Arterial Clamping

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Abstract. Inelastic phenomena such as stress softening and unrecoverable inelastic deformations induced by supra-physiological loading have been observed experimentally in soft tissues such as arteries. These phenomena need to be accounted for in constitutive models of arterial tissues so that computational models can properly predict the outcome of interventional procedures such as arterial clamping and balloon angioplasty that involve non-physiological tissue loading. Motivated by experimental data, a novel pseudo-elastic damage model is proposed to describe discontinuous softening and permanent deformation in arterial tissues. The model is fitted to experimental data and specific material parameters for 9 abdominal and 14 thoracic aortas are provided. Furthermore, the model was implemented in a finite element code and numerically analyzed with respect to experimental tests, i.e. cyclic uniaxial tension in circumferential and longitudinal directions. Results showed that the model is able to capture specific features including anisotropy, nonlinearity, and damage-induced inelastic phenomena, i.e. stress softening and permanent deformation. Finite element results of a more complex boundary-value problem, i.e. aortic clamping considering the three aortic layers, residual stress, non-symmetric blood pressure after clamping, and patient-specific data are also presented.

Keywords: Constitutive modeling, supra-physiological loading, damage, finite element model, aortic clamping

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