The Effect of a Constitutive Formulation on Limb Flexion-Induced Stresses in the Human Femoropopliteal Artery: a Patient-Specific Study

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Peripheral arterial disease (PAD) involves the development of atherosclerotic lesions that restrict the flow of blood to tissues downstream. The femoropopliteal artery (FPA) experiences complex mechanical deformations during daily activities, potentially contributing to the prevalence of PAD and unfavorable treatment outcomes. These deformations generate significant intramural stresses and strains, resulting in arterial injury, disease progression, and restenosis following treatment. Computational modeling offers a way to improve the repair of the FPA; however, the accuracy of these simulations relies on the selection of an appropriate constitutive model that describes arterial behavior. In this study, a finite element model of the FPA in gardening (60°) and straight (180°) postures was constructed based on a CT scan, longitudinal pre-stretch, and biaxially determined mechanical properties from a cadaveric experiment. Two invariant-based constitutive models were compared to evaluate their ability to accurately capture the stresses of the FPA. The results demonstrated that the Neo-Hookean model significantly increased FPA stresses, but it underestimated non-uniform stress distribution. In the gardening limb posture, employing the Neo-Hookean model led to a 15.3% rise in median Mises stresses. Median Mises stresses increased from 39.5 kPa with classic two-fiber Holzapfel–Gasser–Ogden formulations to 45.3 kPa with Neo-Hookean model. Additionally, the model incorporating the Neo-Hookean constitutive model exhibited lower areas of high-stress concentrations (>100 kPa): 4.5% compared to 6.4% in the gardening posture. The discrepancy between the results obtained from the Neo-Hookean model and the classic two-fiber Holzapfel-Gasser-Ogden formulations highlights the importance of selecting an appropriate constitutive model that accurately describes arterial behavior in computational modelings.

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