On the Impact of Residual Strains in the Stress Analysis of Patient-Specific Atherosclerotic Carotid Vessels: Predictions Based on the Homogenous Stress Hypothesis

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Abstract

The identification of carotid atherosclerotic lesion at risk for plaque rupture, eventually resulting in cerebral embolism and stroke is of paramount clinical importance. High stress in the fibrous plaque cap has been proposed as risk factor. However, amongst others, residual strains influence said stress predictions, but quantitative and qualitative implications of residual strains in this context are not well explored. We therefore propose a multiplicative kinematics-based Growth and Remodeling (G&R) framework to predict residual strains from homogenizing tissue stress and then investigate its implication on plaque stress. Carotid vessel morphology of four patients was reconstructed from clinical Compute Tomography-Angiography (CT-A) images and equipped with heterogeneous tissue constitutive properties assigned through a histology-based artificial intelligence image segmentation tool. As compared to a purely elastic analysis and depending on patient- specific morphology and tissue distributions, the incorporation of residual strains reduced the maximum wall stress by up to 30% and resulted in a fundamentally different distribution of stress across the atherosclerotic wall. Regardless residual strains homogenized tissue stresses, the fibrous plaque cap may persistently be exposed to spots of high stress. In conclusion, the incorporation of residual strains in biomechanical studies of atherosclerotic carotids may be important for a reliable assessment of fibrous plaque cap stress.

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