Cardiovascular Mechanics: Perspectives and Challenges

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Starting with a short historical introduction we continue to explain the challenges within mechanobiology and the interrelations of the field on an example of a diseased carotid artery generating an atherosclerotic plaque. For such a problem mechanics, biology, engineering and medicine need to be brought together to perform appropriate modeling and simulations of the involved biological tissues from the structural to the macroscopic level.

Sources of changes are cells, whereby the cell structure dictates tissue function via mechanotransduction, i.e. the conversion of mechanical stimuli to biochemical signals. The mechanics of mechanotransduction turns out to be key to better understand blood vessels in health and disease. Do we need continuum mechanics to tackle such problems?

We discuss vessel walls in more details, in particular the occurrence of residual stresses, the normal development of elastic arteries, with the inherent different structure of collagen in the individual layers, requiring appropriate modeling; we also focus on hypertension and aging. We continue with pathologies such as atherosclerosis and relate to interventional procedures such as balloon angioplasty requiring constitutive damage models; abdominal and cerebral aneurysms are briefly explained. Finally, multi-scale modeling is challenged. Drug therapy or biocompatible body part replacements depend on knowing how a protein/cell behaves in context and in its interaction with the surrounding tissues to generate function at a higher level. Hence, the fundamental goal is to base research on a multi-scale approach where simulations and experiments must go together in order to achieve this integrative knowledge.

Reference

G.A. Holzapfel and E. Kuhl (eds.): "Computer Models in Biomechanics: From Nano to Macro". Springer, 2013, p. 413