EFFECTS OF TISSUE STRUCTURE ON THE GEOMETRICAL OUTPUTS OF ARTERIAL REMODELING DUE TO CHANGES IN PRESSURE AND FLOW

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Introduction

Arterial remodeling in response to sustained alterations in blood pressure and/or flow induces changes in vessel geometry, structure, and composition. A majority of theoretical studies on remodeling have assumed that new mass is formed via a proportional production of load-bearing constituents, namely elastin, collagen, and smooth muscle. The objective of this study is to build a mathematical model that enables evaluation of the effects of mass redistribution among structural components and changes in collagen fiber configuration on the geometrical outputs of arterial remodeling.

Methods

An artery is considered to be a thick-walled cylindrical tube which in the state of no loads contains residual strains and stress. The arterial tissue is modeled as a constrained mixture of collagen, elastin, and smooth muscle cells, all of which have their individual mechanical properties and mass fractions. Following the approach proposed in [Rachev et al., 2013] we formulate the following inverse problem: given the arterial pressure, blood flow, and the constitutive equations of the tissue, determine the zero-stress configuration of the artery such that the deformed flow-induced shear stress at the arterial lumen, the circumferential stress distribution across the arterial wall, the axial stress in the arterial wall, and the pressure-radius modulus in the deformed configuration have certain prescribed values.

Results

As an illustrative example, we consider pressure- and flow-induced remodeling of a mouse common carotid artery. The geometrical dimensions and passive strain energy function of the arterial tissue are taken from [Wan et al., 2010]. The inverse problem was solved numerically for pressures from normotensive (100 mmHg) to hypertensive (240 mmHg) and flows rates that are up to five-fold the baseline value. Three particular cases were considered to evaluate the effects of presence or lack of changes in structural components mass fractions and collagen fiber configuration.

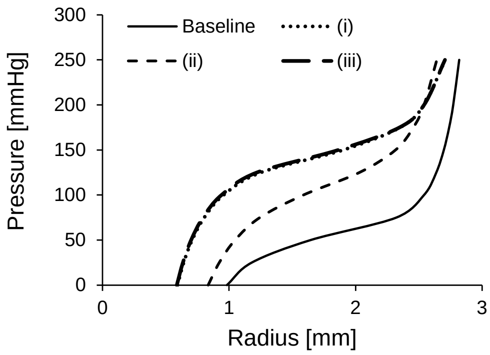

Figure 1: Deformed inner radius vs. mean pressure of a normotensive (baseline) and remodeled vessels (200 mmHg) for different remodelling scenarios.

Discussion

The results obtained show that accounting for changes in collagen fiber configuration significantly impacts theoretical predictions of pressure-induced arterial remodeling outcomes (i vs ii), while accounting for changes in the mass fractions of structural constituents has comparatively minimal influence (i vs iii). Flow-induced remodeling outcomes were relatively insensitive to both examined factors. There is a need of additional experimental studies that can promote further identification of the plausible scenarios of arterial remodeling and serve as a basis for building increasingly reliable mathematical models.

References

Rachev, A., et al., Ann Biomed Eng (published on line) DOI: 10.1007/s10439-012-0727-9, 2013.

Wan W. et al., Ann. Biomed. Eng., 38 : 3605 - 3617, 2010.