THEORETICAL STUDY OF THE EFFECTS OF MUSCULAR TONE ON ADAPTIVE AND MALADAPTIVE REMODELING OF ARTERIES DUE TO HYPERTENSION

Aristotelis Agianniotis[1], Nikos Stergiopulos[1], Raymond P. Vito[2], Tarek Shazly[3], Alexander Rachev[2,3]

[1]Laboratory of Hemodynamics and Cardiovascular Technology Ecole Polytechnique Fédérale de Lausanne, Switzerland; [2]George W. Woodruff School of Mechanical Engineering Georgia Institute of Technology, USA; [3]College of Engineering and Computing, University of South Carolina, USA

Introduction

A sustained increase in pressure causes arterial remodeling. An adaptive response manifests as a change in geometry that preserves the local mechanical environment of vascular cells under elevated pressure. Maladaptive remodeling could result from a variety of dysfunctional biological processes, and is characterized by the incomplete restoration of the baseline mechanical environment. Due to the multi-factorial and complex nature of remodeling, it is exceedingly difficult to evaluate the relative importance of any one factor in isolation in bench-top or animal studies. This study is devoted to a theoretical simulation of the effects of smooth muscle tone on the remodeling response to hypertension.

Methods

An artery is considered to be a thick-walled cylindrical tube made of nonlinear, elastic, incompressible material. Following the methodology proposed in [Rachev et al., 2013], the outcomes of remodeling are determined from the solution of the following inverse problem. Given the values of hypertensive pressure and two parameters associated with vascular tone and arterial mass, determine the outcomes of remodeling in terms of altered zero-stress state and deformed geometry from the conditions that the circumferential stress distribution and mean axial stress are restored to baseline values.

Results and Discussion

The constitutive formulation of the passive mechanical properties and active stress due to the muscular tone were adopted from [Wagner and Humphrey, 2011] and [Rachev and Hayashi, 1999], respectively. The inverse problem formulated above was solved for hypertensive pressures (100-160 mmHg) with variation of the muscular tone via normalized activation parameter k_s and normalized cross-sectional area k_a.

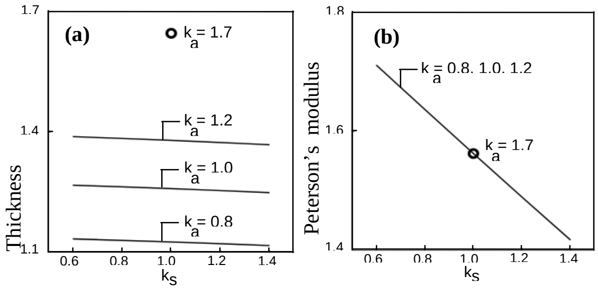

Figure 1. Deformed thickness (a), and Peterson's modulus (b) normalized by the values at P=100 mmHg vs. SMCs activation parameter ks for the case of maladaptive remodeling at P=160 mmHg. The opened circle corresponds to the case of adaptive remodeling.

Among vessels made of identical material there are an infinite number of zero-stress, and consequently deformed, configurations that have identical stress distributions for given pressure and activation parameter. In the case of endothelial dysfunction, the reduced production of NO causes an increase of muscular tone in concert with elevated blood pressure. Arterial stiffening, which is a clinical indicator and predictor of cardiovascular diseases, increases as a result of remodeling. This effect decreases with the increase in the vascular tone, which serves as a compensatory mechanism.

References

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