CHARACTERIZATION OF VISCOELASTICITY AND DAMAGE ON ARTERIES FROM HYPOXIC GUINEA PIGS

Alejandro Bezmalinovic (1), Álvaro Navarrete (1), Claudio García-Herrera (1), Diego Celentano (2), Marcos Latorre (3), Emilio A. Herrera (4)

. Laboratorio de Biomecánica y Biomateriales, Departamento de Ingeniería Mecánica, Universidad de Santiago de Chile, Chile; 2. Departamento de Ingeniería Mecánica y Metalúrgica, Pontificia Universidad Católica de Chile, Chile; 3. Centro de Investigación e Innovación en Bioingeniería (Ci2B-UPV), Universitat Politécnica de Valencia, España; 4. Programa de Fisiopatología, Facultad de Medicina, Instituto de Ciencias Biomédicas, Universidad de Chile, Chile.

Introduction

Viscoelasticity and mechanical damage are two main sources of energy dissipation in arteries subjected to mechanical loading, that lead to a strain-rate and load-frequency dependent response, along with softening and hysteresis under cyclic loading.

At high altitudes (above 2500 masl) animals are exposed to a condition induced by a low partial-pressure of oxygen, known as “hypobaric hypoxia”. Chronic hypoxia during development impairs the function and structure of several organs [1], however, few is known about the effects of high-altitude hypoxia on the biomechanical characteristics of arteries.

The objective of this work is to characterise the passive viscoelastic and damage properties of arterial tissue exposed to hypoxia, aiming at improving the understanding of its mechanical response.

Methods

All procedures were approved by the Bioethics Committee of the Faculty of Medicine, Universidad de Chile. Guinea pigs were studied. Animals were randomly separated into two groups, “control” and “hypoxic”. Subjects assigned to the hypoxic group were subjected to hypoxia using an hypobaric chamber. Once euthanized, rectangular samples were cut from the thoracic aorta of each subject.

Samples were assessed for in-vitro displacement-controlled uniaxial relaxation and biaxial tensile tests.

The mechanical characterization of arteries is based upon the results of experimental tests.

The constitutive model consists of a damage model [2] associated with the isochoric strain-energy component of an anisotropic hyperelastic model [3], and an orthotropic viscoelastic model using a multiplicative decomposition of the deformation gradient and a non-equilibrated strain-energy component in terms of inviscid Hencky strains [4], further assuming material incompressibility and isothermal conditions.

Results

The passive viscoelastic and damage mechanical behavior of the artery wall was group-wise characterized using a curve-fitting procedure applied to the experimental stress-stretch curves.

The material model parameters determined were associated to a finite-element simulation of a bulge pressurization test, in order to predict the pressure associated with the onset of damage.

We analyzed a quarter-disk shaped structure, fixed along its curved perimeter and loaded by a deformation-dependent force per unit area always normal to the acting surface (see Figure 1).

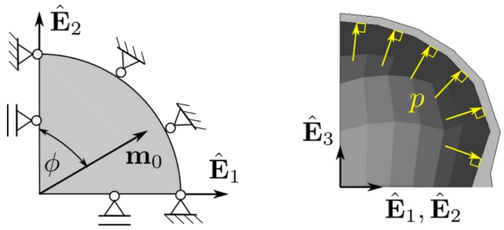

Figure 1: Schematic representation of the bulge test simulation. Undeformed (left) and deformed (right) configurations. Boundary conditions, transverse-isotropy direction ‘$\mathbf{m}_0$’ (characterized by an angle ‘φ’) and acting pressure ‘p’.

Discussion

Finite-element simulations of the bulge pressurization test delivered pressures associated with the onset of damage that are compatible with a mixed hypertension condition.

Therefore, the viscoelastic-damage characterization proposed is adequate to describe the passive mechanical response of arterial tissue from hypoxic guinea pigs, providing reliable parameters for its numerical simulation.

References

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