

The mechanical properties of the porcine coronary arterial wall determined with a mixed experimental-numerical approach

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The mechanical properties of the porcine coronary arterial wall determined with a mixed experimental-numerical approach

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Introduction

The coronary arterial wall is anisotropic and has a highly non-linear stress-strain relationship [1-3]. A widely used method to measure this anisotropic non-linear behavior is to evaluate the response of the arterial wall when subjected to simultaneous inflation and axial extension [1-3]. Figure 1 shows a characteristic result obtained with such an ex vivo experiment (solid line) on a porcine LAD (C.N. van den Broek, unpublished data).

The aim of this study is to investigate whether this characteristic behavior can be described by a relatively simple, single layer, fiber reinforced neo-Hookean material model.

Methods

The arterial wall is modeled as an incompressible fiber reinforced solid tube. This model was first introduced by Holzapfel et al. [3] and extended by van Oijen [4] and Driessen et al. [5]. Here, only the main features of the model are described, for the exact derivation of the constitutive equations, see Driessen et al. [5].

The matrix material is modeled as an incompressible neo-Hookean solid with shear modulus G . The fibers are modeled one-dimensionally and are arranged as a cross-ply with main angle μ , standard deviation of the fiber distribution σ and total fiber volume fraction φ_{tot} . Two parameters (k_1, k_2) determine an exponential stress-strain relation of the fibers.

The difference between the experimental- and numerical response is minimized using the Levenberg-Marquardt algorithm. Since σ is relatively insensitive compared to μ it is held constant at 10° . φ_{tot} is held constant at 0.5 due to its dependence on the other parameters. Therefore, a set of four material parameters (G, k_1, k_2, μ) is optimized.

Results

Although the estimated material parameters can describe the axial force accurately, the computation of the radius deviates significantly for the larger axial stretches at low pressures (Figure 1). Furthermore, the estimated material parameters found are significantly different for the three different axial stretches (table 1).

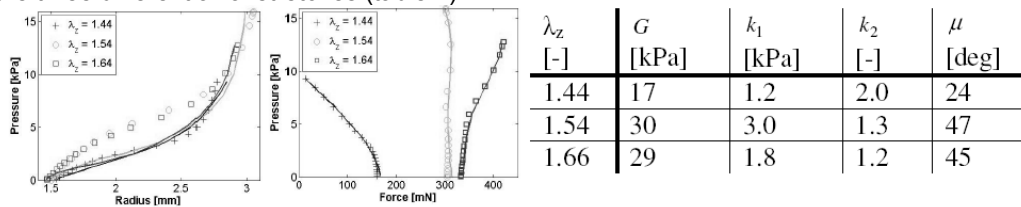


Figure 1: The experimental (solid) and numerical results (+, o, □) of the radius (left) and axial force (right) for the three axial stretches (λ_z)(+, o, □) and the material properties listed the table.

Discussion and conclusions

Although the model gives reasonable results for the axial force, the radius at low pressure deviates significantly from the experimental data. A single parameter set describing the material behavior was not found. A possible reason for this are the assumptions made for φ_{tot} and σ . By finding a way to overcome the dependency problem of φ_{tot} the estimation results could be improved. Furthermore, since the material model is more a phenomenological than a microstructural model, the model might be improved by extending it with residual stress and (passive) smooth muscle behavior.

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