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Document status and date:
Published: 01/01/2008

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
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Link to publication

Download date: 04. Oct. 2023

Mechanical properties of the porcine coronary artery

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Introduction

Knowledge of the mechanical properties of living arteries is important to understand vascular function during disease and the effect of interventions, such as balloon inflation. The aim of this research is to propose general parameter values for the fiber-reinforced material model proposed by Driessen et al. (2005) that can describe the arterial wall behavior of the porcine left anterior descending coronary artery (LAD).

Material & methods

Pressure-radius and pressure-axial force behavior of 6 porcine LADs were measured in an ex-vivo model (fig. 1). Measurements were performed at physiological length, defined as the segment length at which the axial force is relatively insensitive to changes in pressure.[1]
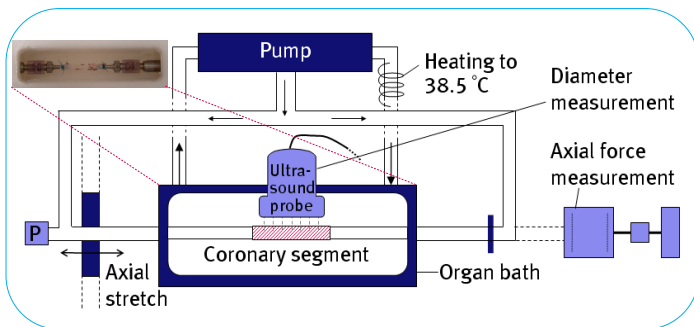

Fig. 1: Ex-vivo model for the arterial mechanical behavior assessment.

A four-parameter material model[2], describing the artery wall as a fiber-reinforced Neo-Hookean material with a distribution on the fiber orientation β (fig. 2), was fitted to the experimental data, yielding the optimal material parameters for each LAD. Next, the mean values of the optimal material parameters were applied to the geometry of each tested LAD. The error of the determined pressure-radius behavior relative to the experimental data was compared to the error when the optimal material parameters were used.
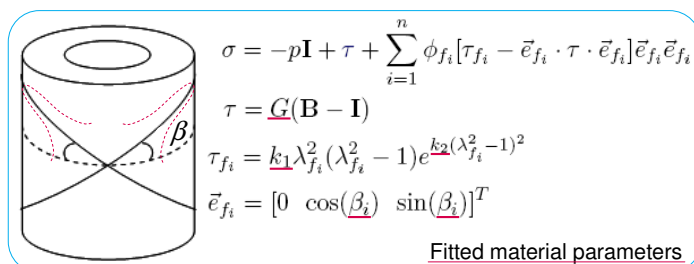

$$\sigma = -p\mathbf{I} + \tau + \sum_{i=1}^{n} \phi_{f_i}[\tau_{f_i} - \vec{e}_{f_i} \cdot \tau \cdot \vec{e}_{f_i}]\vec{e}_{f_i}\vec{e}_{f_i}$$

$$\tau = \underline{G}(\mathbf{B} - \mathbf{I})$$

$$\tau_{f_i} = \underline{k_1}\lambda_{f_i}^2(\lambda_{f_i}^2 - 1)e^{\underline{k_2}(\lambda_{f_i}^2 - 1)^2}$$

$$\vec{e}_{f_i} = [0 \ \cos(\underline{\beta_i}) \ \sin(\underline{\beta_i})]^T$$

Fitted material parameters

Fig. 2: Four-parameter fiber-reinforced Neo-Hookean material model[2].

Results

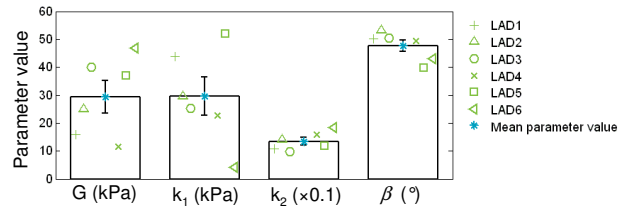Optimal material parameters and the mean values ± sem:

Fig. 3: Parameter values resulting from the material model fits to the experimental dataset of each LAD & the mean parameter values ±sem.

The pressure-radius behavior of the 6 LADs is shown in figure 4. The average relative error increased from 1.9 ±0.6% for the pressure-radius behavior determined with the optimal parameter sets, to 6.0 ±1.9% for the behavior determined with the mean parameter set.
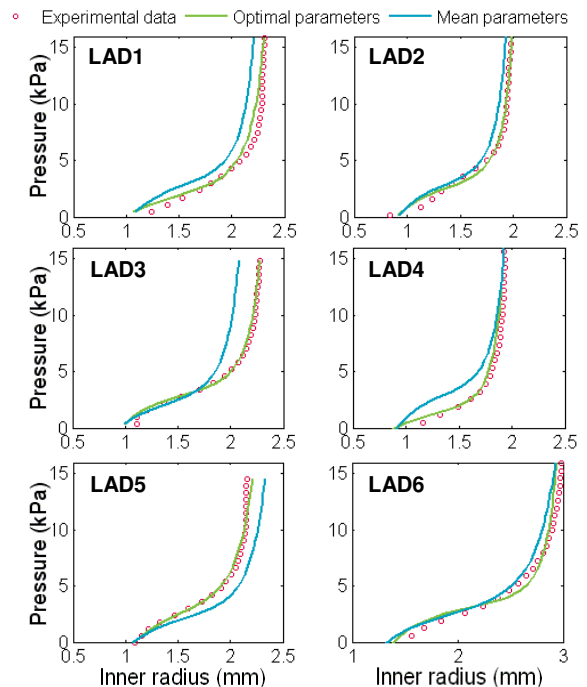

Fig. 4: Pressure-radius behavior determined experimentally, with the optimal parameter set for each LAD, and with the mean parameter set.

Conclusion

A general parameter set for the described fiber-reinforced material model is proposed, with which the pressure-radius behavior of the porcine LAD can be well-described.

References

[1] Weizsäcker and Pascale (1977), *Basic Res Cardiol* **72**, p.619-627.
[2] Driessen et al. (2005), *J Biomech Eng* **127**, p.494-503.