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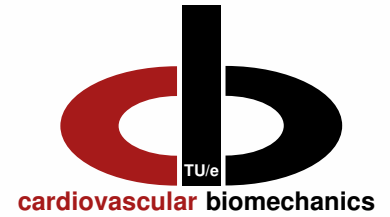
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# A generic material model of the passive porcine coronary artery

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## Introduction

A mechanical model of the vascular tree would facilitate the improvement of (balloon-)catheters and stents. The aim of this research is to propose generic model and geometric parameter values for a fiber-reinforced material model<sup>2</sup> that describes the arterial wall behavior of the passive porcine coronary artery.

## Material & methods

Measurement pressure-inner radius (P- $r_i$ ) and P- $\Delta F$  axial force (P- $\Delta F$ ) relations at physiological stretch<sup>1</sup> ( $\lambda_p$ ) of the porcine left anterior descending coronary artery (LAD) and the material model.

Coronary artery under loading:

Fiber reinforced Neo-Hookean model<sup>2</sup> with 4 fit parameters:

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

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

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

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

Model fit of P- $r_i$  and P- $\Delta F$  relations giving the optimal parameter set  $\Psi_i$  (i=1-7) and the generic sets  $\Psi_m$  and  $\bar{\Psi}$ .

Parameter set  $\Psi: \{G, k_1, k_2, \beta\}$

Model approximation of  $r_i$  at physiological pressure ( $P_p$ ) and stretch using  $\Psi_m$  &  $\bar{\Psi}$  and generic mean values for the geometric parameters  $\lambda_p$ , collagen fiber fraction  $\phi_i$ , and wall thickness to  $r_i$  ratio  $\gamma$ , with:

$$\bar{\lambda}_p = 1.39 \quad \bar{\phi}_i = \frac{\langle h_i \rangle}{h} = 0.4 \quad \bar{\gamma} = \frac{\langle h \rangle}{r_i} = 0.09$$

Compare deviations of model approximations from experimentally measured P- $r_i$  and P- $\Delta F$  relations ( $\bar{\delta}_r$  &  $\bar{\delta}_F$  resp.) using  $\Psi_{1-7}$ ,  $\Psi_m$  and  $\bar{\Psi}$ .

Fig. 1: Protocol used to obtain the generic model parameters.

## Results

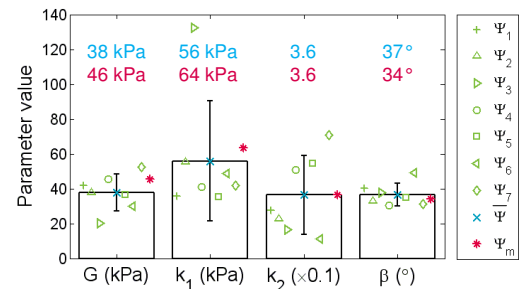


Fig. 2: Parameter values resulting from the material model fits to the experimental data set of each LAD, the mean values  $\pm$ SD (bars & error bars) and the generic parameter sets  $\Psi_m$  and  $\bar{\Psi}$  and their values.

The different parameter sets  $\Psi_i$ ,  $\Psi_m$ , and  $\bar{\Psi}$  show spread in the parameter values (fig. 2). The experimental P- $r_i$  and P- $\Delta F$  relations can be fitted well with the model using  $\Psi_i$  (fig.3 & table). The deviation  $\bar{\delta}_r$  increased when a generic set was used (0.5% $\approx$ 8  $\mu$ m to 2% $\approx$ 30  $\mu$ m).  $\bar{\delta}_F$  was comparable for  $\Psi_i$  and  $\Psi_m$  (0.47 vs 0.59 $\approx$ 30 mN), whereas  $\bar{\delta}_F$  increased when  $\bar{\Psi}$  was used.

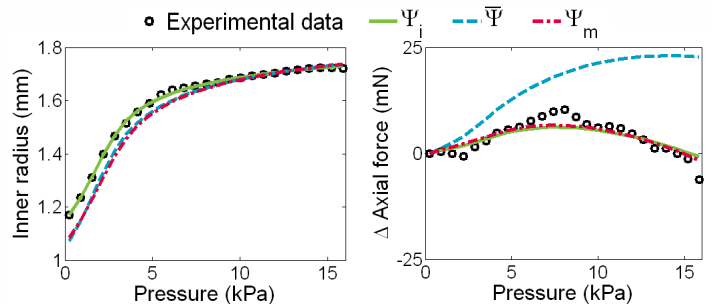


Fig. 3: Example of the P- $r_i$  and P- $\Delta F$  relation of a porcine LAD measured experimentally, the optimal model fit using  $\Psi_i$ , and the generic model approximation using  $\Psi_m$  and  $\bar{\Psi}$ .

Table: Mean deviations  $\pm$  SD of the model approximations from the experimental P- $r_i$  and P- $\Delta F$  relations using the different parameter sets.

	$\Psi_i$	$\bar{\Psi}$	$\Psi_m$
$\bar{\delta}_r$	0.005 $\pm$ 0.003	0.019 $\pm$ 0.01	0.019 $\pm$ 0.01
$\bar{\delta}_F$	0.47 $\pm$ 0.23	1.47 $\pm$ 0.94	0.59 $\pm$ 0.20

## Conclusion

Two generic parameter sets in combination with generic geometric values have been proposed of which the set  $\Psi_m$  shows a better approximation of the experimental data. Applying this generic model, using the set  $\Psi_m$ , to a single radius measurement at physiological loading, allows prediction of the P- $r_i$  and P- $\Delta F$  relations of the porcine LAD with an accuracy of 30  $\mu$ m and 30 mN on average.