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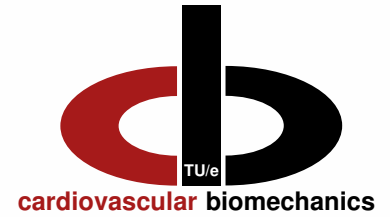
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A generic material model of the passive porcine coronary artery

Chantal van den Broek, Arjen van der Horst, Marcel Rutten & Frans van de Vosse



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 model² that describes the arterial wall behavior of the passive porcine coronary artery.

Material & methods

Measurement pressure-inner radius (P- r_i) and P- ΔF axial force (P- ΔF) relations at physiological stretch¹ (λ_p) of the porcine left anterior descending coronary artery (LAD) and the material model.

Coronary artery under loading:

Fiber reinforced Neo-Hookean model² 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- ΔF relations giving the optimal parameter set Ψ_i (i=1-7) and the generic sets Ψ_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 Ψ_m & $\bar{\Psi}$ and generic mean values for the geometric parameters λ_p , collagen fiber fraction ϕ_i , and wall thickness to r_i ratio γ , 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- ΔF relations ($\bar{\delta}_r$ & $\bar{\delta}_F$ resp.) using Ψ_{1-7} , Ψ_m and $\bar{\Psi}$.

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

Results

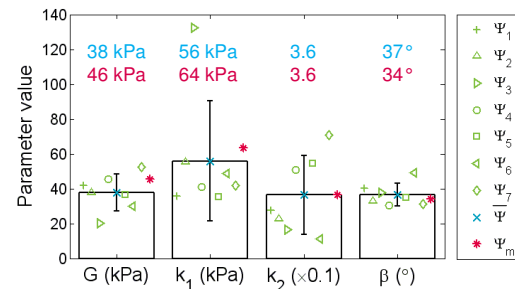


Fig. 2: Parameter values resulting from the material model fits to the experimental data set of each LAD, the mean values \pm SD (bars & error bars) and the generic parameter sets Ψ_m and $\bar{\Psi}$ and their values.

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

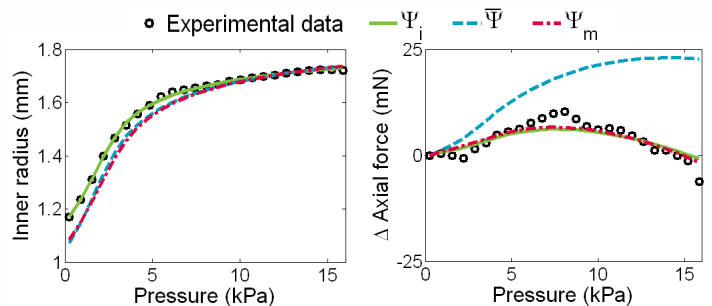


Fig. 3: Example of the P- r_i and P- ΔF relation of a porcine LAD measured experimentally, the optimal model fit using Ψ_i , and the generic model approximation using Ψ_m and $\bar{\Psi}$.

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

	Ψ_i	$\bar{\Psi}$	Ψ_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 Ψ_m shows a better approximation of the experimental data. Applying this generic model, using the set Ψ_m , to a single radius measurement at physiological loading, allows prediction of the P- r_i and P- ΔF relations of the porcine LAD with an accuracy of 30 μ m and 30 mN on average.