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EVALUATION OF A COMPUTATIONAL MODEL FOR DRUG ACTION ON CARDIAC TISSUE

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Introduction. In our so-called CellDrum^{TM} device we inflate cell-seeded circular membranes and measure their center deflection in order to determine the mechanical effect of the cells on the membrane. Those inflation tests produce pressure-deflection curves that enable us to determine material parameters for our constitutive model of the cardiac tissue. The auto-contractile cardiac monolayer changes the deflection of the inflated membrane, [1]. In this paper we draw special attention on the modeling of drug action (f.i. Lidocaine) within the electromechanically coupled Finite Element model.

Computational Model. We discretize the thin circular membrane ($16mm$ in diameter and $0.008mm$ in thickness) with 9-noded heterosis Mindlin shell finite elements in a geometrical nonlinear framework. Following the cardiac tissue model of Hunter et al. [2] the Cauchy stress tensor $\boldsymbol{\sigma}$ is described by equation (1) as an additive split of the passive and active part $\boldsymbol{\sigma}_p$ and $\boldsymbol{\sigma}_a$ respectively

$$\boldsymbol{\sigma} = \boldsymbol{\sigma}_p + \boldsymbol{\sigma}_a = 2J^{-1}\boldsymbol{B}\frac{\partial \Phi}{\partial \boldsymbol{B}} - p\boldsymbol{I} + T(t, \boldsymbol{B}, [Ca^{2+}]_i)\boldsymbol{I} \ , \tag{1}$$

with Φ a hyperelastic strain energy, J the determinant of the deformation gradient, $\boldsymbol{B}$ the left Cauchy-Green tensor, p the hydrostatic pressure, $\boldsymbol{I}$ the identity tensor, T a scalar related to the active stress, t the time and $[Ca^{2+}]_i$ the inner calcium concentration that mainly drives the contractility of cardiac cells. We describe T by a system of ordinary

differential equations including the McAllister-Noble-Tsien model [3]

$$\frac{\partial V_m}{\partial t} = \frac{1}{C_m}\left(I_{stim} - \sum_{i=1}^{9} I_i(g_{x_1}, g_{x_2}, ...)\right) \quad (2)$$

$$\frac{\partial g_x(V_m)}{\partial t} = \alpha_x^+(V_m)(1-g_x) + \alpha_x^-(V_m)g_x \quad (3)$$

that prescribes the time course of the action potential V_m and the ionic gates g_x which in turn control the ionic currents I_i.

Model Evaluation.

As illustrated in figures 1 and 2 we evaluate the model with respect to its mechanical and electrophysiological components and give an outlook on upcoming model improvements.

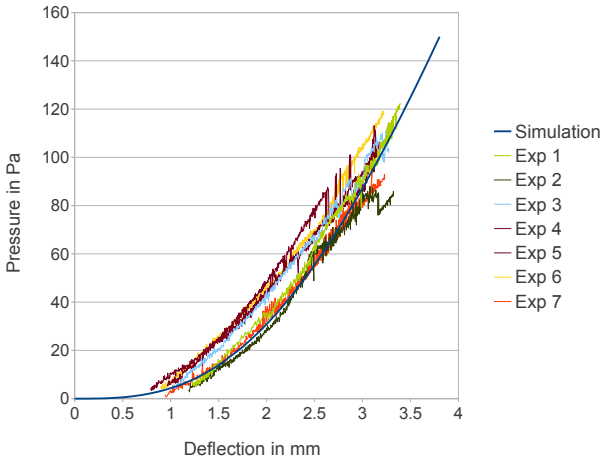

Figure 1: Comparison of pressure-deflection experiments vs. simulation results

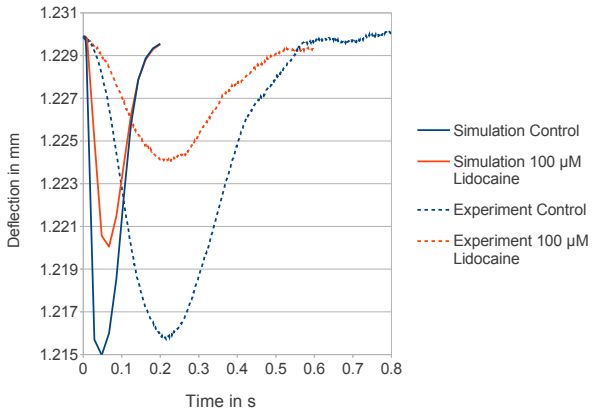

Figure 2: Comparison of experimental and simulation results

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