CARDIAC ABLATION AS A MULTI-PHASE THERMOPOROELASTIC CONTINUUM UNDER LARGE DEFORMATION

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Abstract. Cardiac ablation is a way of treating pathological electric patterns in the heart by burning strategically chosen points with a catheter. The entire process is extremely complex, as it involves: the generation of heat through an electromagnetic field at the catheter's tip, the increase of heat of the heart because of the catheter, the dissipation of heat in the tissue because of both diffusion and blood circulation, the deformation of the tissue induced by the burn injury, the increase of blood pressure because of the swelling and temperature, the formation of oedema through leakage from the lymphatic system, and the cooling of the catheter because of the blood within the heart chamber. This is of course a list of only the main mechanistic elements of the treatment, but many other factors are involved.

This talk will address the mathematical modeling of this phenomenon through the theory of porous media. Our approach will be mainly that of mathematical generality and physical accuracy, by building upon a thermodynamically consistent model developed in [1] through large deformations thermoelasticity. Our extension leverages multi-compartment models for cardiac perfusion [2] with the theory of thermoporoelasticity [3], and uses an ad-hoc approach for modeling the Gibbs potential, which has not yet been characterized in soft tissues. One fundamental technical difficulty in this context is that of computing a reference configuration that is in mechanical equilibrium. To circumvent this, we propose an extension of the inverse elasticity model [4] into a quasi-static poroelastic model that extends other simplified approaches [5] to yield a general framework for computational models of porous soft tissue. All claims will be validated through numerical tests.

Keywords: Poroelastic media, Thermodynamics, Inverse elasticity, Computational mechanics

Mathematics Subject Classifications (2010): 65F10, 74S05, 76S05

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