Multiphysics Modeling of a Minimally Invasive Tissue Ablation Methodology

J. S. Crompton[1], J. Thomas[1], K. Koppenhoefer[1]

[1]AltaSim Technologies, Columbus, OH, USA

Abstract

Necrosis of human tissue can typically be obtained by exposure to temperatures below 40°C or above +50°C. However, inherent variability in tissue properties, the complexity of tissue response and dissipation of thermal energy by local perfusion or blood flow can make the development of routine, predictable in-vivo approaches to produce necrosis difficult. Although a number of thermal ablation techniques exist, optimization of electrode design and operational practices is difficult using traditional in-vivo or in-vitro based testing. Computational analysis is being used to simulate device performance and enable the development of safer operating procedures and instrument designs.

For ablation technology in which a current carrying electrode is inserted into a blood vessel and pressed against the vessel wall, deformation of the tissue can occur that changes the degree of local contact and thus affects the efficiency of heat transfer into the surrounding tissue. To obtain efficient tissue ablation mechanical contact must be maintained between the ablation electrode and the site of interest (Figure 1).

In addition, local perfusion and blood flow can lead to increased dissipation of thermal energy. In this work, COMSOL Multiphysics has been used to simulate the coupled effects of solid mechanics with mechanical contact associated with vessel wall deformation, laminar flow due to blood flow through the vessel, bioheat transfer due to perfusion and flow of electric current to produce Joule heating of the electrode. Figure 2 shows an example of the temperature distribution obtained from a three-dimensional model incorporating elastic deformation, fluid flow, electric potential, and heat transfer.

The model has been used to isolate the effect of critical variables on the successful operation of the tissue ablation device.

Figures used in the abstract

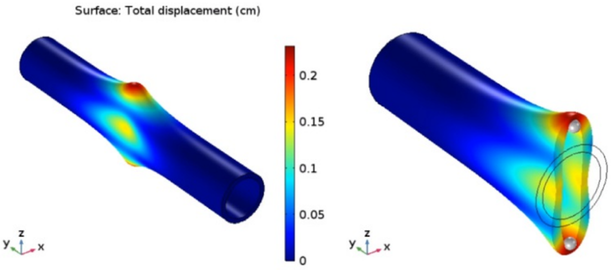

Figure 1: Figure 1: Displacement plots of the thermal ablation electrodes in contact with the wall of a blood vessel.