Multiphysics Modeling of Electrode-Driven Renal Denervation for Hypertension Treatment

M. Miliani[1], F. Piccagli[1], C. Silvestro[1]

[1]Medtronic Invatec S.p.A., Roncadelle, Italy

Abstract

Introduction: Chronic arterial hypertension (HTN) is a pathological condition characterized by prolonged high level of arterial blood pressure causing major damages to several human body apparata. Renal sympathetic denervation (RDN) has been found to effectively reduce systemic blood pressure. Metallic electrodes can be placed on an endovascular device connected to external radio frequency (RF) generator: RDN is achieved via percutaneous delivery of RF energy into the renal artery (ref. to Figure 1). In the present work, a multiphysics finite element (FE) numerical model of an electrode-driven RDN setup has been developed (ref. to Figure 2). The model was used to investigate different electrode designs, materials and configurations. The effect of varying environmental boundary conditions was also analyzed.

Method: The modeled configuration derives from a previously developed ex-vivo bench setup consisting of a porcine renal artery immersed into a 37 °C bath and a stationary flow forced through the vessel. According to the bench setup, the numerical model included a deployed electrode inside a vessel, in contact with the inner artery surface. The electrode functioning was simulated in a unipolar configuration, placing the generator ground plate at the bottom of the bath (ref. to Figure 3). Electrode geometries and materials were varied according to various inputs. Variation of the boundary conditions was investigated according to typical treatment configurations (different generator wattages, flow rates and fluid properties).
The multiphysical model was developed using CFD, electrical and heat exchange physical parameters taken from literature. Mesh size was selected after a sensitivity analysis.

Results and Discussion: The ablation performances were found to be related to electrode design and environmental boundary conditions applied. The temperature and the current density concentration were found to be dependent on electrode geometry and material parameters. The numerical model provided the temperature distribution within the vessel wall, thus allowing comparison to expected ablation performances in terms of desired lesion pattern (ref. to Figure 4).
The multiphysics simulation of the selected bench setup was capable to account for the coupled fluid-dynamics, electrical and thermal phenomena.

Conclusions: The model developed proved to be effective in supporting the design of new RDN electrode-driven devices, accurately simulating RF energy delivery into the tissues. Consistent indications were provided to device design development team.

Figures used in the abstract

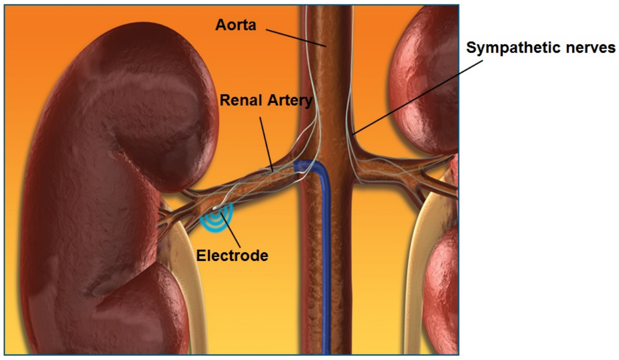


Figure 1

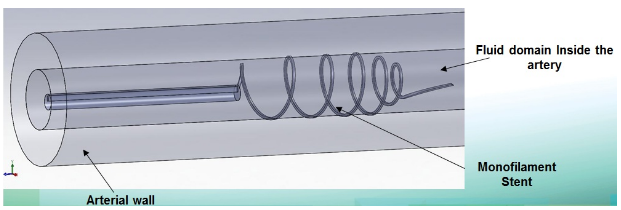


Figure 2

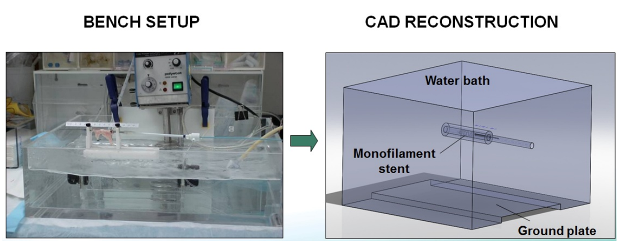
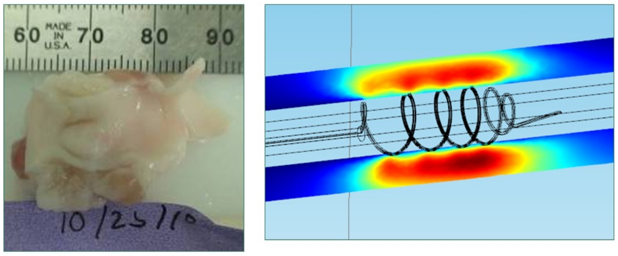


Figure 3



	Temperature [degC]	
Time [s]	Test # 13	Simulations(*)
60	~56	~57
90	~56	~59

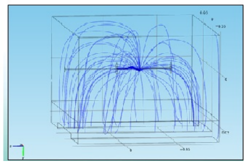


Figure 4