Abstract

Ablative techniques based on radiofrequency (RF) energy are used to produce a safe and localized heating of target biological tissue. In recent years there has been rapid growth in the number of new medical procedures employing these techniques, accompanied by the emergence of new electrode designs and energy delivery protocols. However, there are still many unknowns about the true electro-thermal behavior of energy applicators, along with energy-tissue interaction issues in specific applications.

The main purpose of this PhD Thesis is to gain a better understanding of the electrical and thermal phenomena involved in the heating of biological tissues by RF currents, in order to improve the efficacy and safety of the techniques currently used in clinical practice in different areas, such as cardiac surgery, oncology and dermatology. An additional aim is to suggest technological improvements for designing new applicators. The Thesis combines two methodologies widely used in the field of Biomedical Engineering: computational modeling (mathematical) and experimental (ex vivo and in vivo) tests.

Our cardiac research was focused on improving intraoperative ablation of atrial fibrillation by an epicardial (minimally invasive) approach. To do this, we used mathematical models to assess an impedance measurement system as a method of quantifying the amount of epicardial fat present prior to ablation. We also studied how to improve ablation of the ventricular wall using an endocardial-endocardial approach (interventricular septum) and an endocardial-epicardial approach (ventricular free wall). This involved comparing computer simulations of the efficiency of bipolar and unipolar modes of ablation in terms of the transmurality of the lesion across the ventricular wall.

Surgical oncology focused on RF-assisted hepatic resection. RF heating techniques should be able to minimize intraoperative bleeding and seal vessels and ducts by creating a thermal coagulative necrosis. If this heating occurs in the vicinity of large vessels, there is a risk of damage to this vessel. Using mathematical models

and in vivo experiments, we evaluated whether the effect of blood flow within a large vessel would be able to thermally protect the wall when RF-assisted resection is performed in the vicinity. We also conducted computational and ex vivo and in vivo experimental studies on the electro-thermal behavior of bipolar internally cooled RF applicators. These are a safer alternative to the monopolar applicators due to the fact that RF currents flow almost exclusively through the biological tissue between the electrodes.

The dermatological area focused on improving the treatment of disorders of the subcutaneous tissue (e.g. lipomatosis, lipedema, Madelung disease and cellulite) by a theoretical study of the optimum dosimetry for each case. For this we evaluated the electrical, thermal and thermo-elastic effects of two different structures of subcutaneous tissue during RF heating, as well as the thermal damage to both structures after heating has been quantified.