# MRI-based numerical modeling of cardiac pulsed field ablation (PFA) with sub-microsecond pulses

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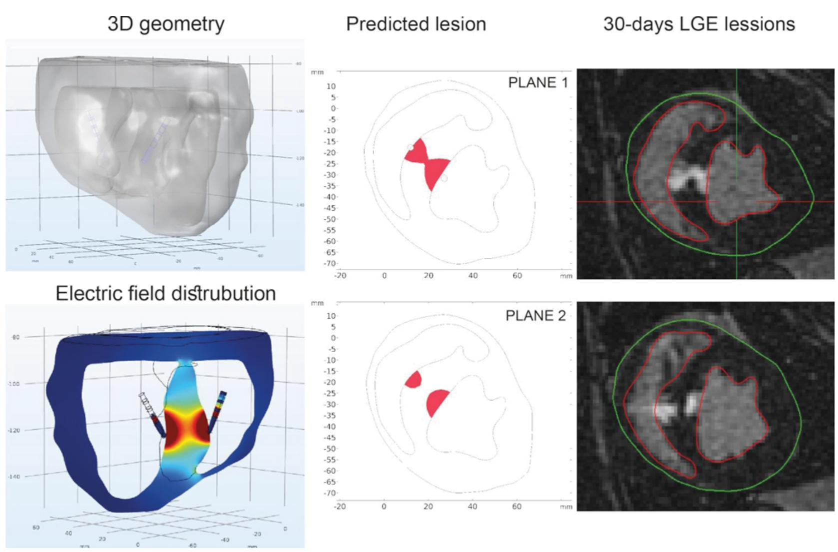
**Background:** The use of irreversible electroporation (IRE) for cardiac ablation in the management of cardiac arrhythmias, known as Pulsed Field Ablation (PFA), has gained the attention of many researchers, physicians and companies. Despite the demonstrated efficacy and safety profiles of the technique, there are still many open questions. One of them deals with the effective electric field thresholds necessary for cardiac tissue ablation.
Contrary to radiofrequency (RF) ablation, where the thermotemporal thresholds for tissue damage are well established, the electric field thresholds for effective IRE are uncertain and depend on the tissue type and the waveform characteristics of the delivered electric field.

**Purpose:** The use of numerical models to understand the electric field distribution and the corresponding lesion for a specific electrode geometry are widely used in IRE for cancer treatment. Models can predict ablation volumes when the field thresholds are known or can be used to estimate the field thresholds when the lesion geometry is established post-treatment. The goal of the present study was to build a subject-specific realistic 3D numerical model to assess the ability of modeling to predict PFA lesions.

**Methods:** PFA experiments were performed in male mongrel dogs following a protocol approved by the Mayo Clinic Institutional Animal Care and Use Committee. Briefly, animals were sedated and intubated, and two non-irrigated deflectable catheters with an 8-mm tip were positioned on both sides of the interventricular septum under fluoroscopy guidance. Submicrosecond pulses were delivered in a bipolar fashion across both catheters. Sequences of pulses of 300 ns duration (or other durations in that range) were repetitively applied with voltage levels in the kV range. 30 days after the procedure, MRI with late gadolinium enhancement (LGE) were acquired to assess the presence of ablation lesions in the treated tissue. Ventricular areas were segmented from MRI images and 3D volumes were created. The generated 3D geometries were imported into software COMSOL Multiphysics. Realistic 3D geometries of the catheters were placed in the same positions than during the experiments, fluoroscopy videos recorded during the procedures were used as a guidance.
The computed electric field intensity distributions were compared to the LGE areas to extract the range of electric field thresholds where the predicted lesion size was compatible with the real size of the LGE areas for each application site and pulsing protocol.

**Results and conclusions:** Our results show how the numerical model is able to reproduce the shape of the LGE fibrotic lesion areas observed 30 days after the procedure. Additionally, the model clearly confirms the dose-dependent lesion sizes observed experimentally. This study supports that numerical modeling is a valuable tool for understanding PFA treatments and that it could be used as patient-specific treatment planning tool.




Modelling example