Asymptotic Analysis of Electrocardiology Modeling after Pulsed Field Ablation

Simone NATI POLTRI

Centre Inria de l'Université de Bordeaux

simone.nati-poltri@inria.fr

We focus on the mathematical study of pulsed electric field ablation (PFA), an innovative cardiac ablation technique for the treatment of cardiac arrhythmias. In particular, we would like to compare it with radio-frequency ablation (RFA), a thermal ablation that is currently the most commonly used technique. This work aims to modify the classical bidomain mode, which describes the propagation of intracellular and extracellular potentials in the heart, to introduce a region ablated by RFA or PFA. Both types of ablation involve isolation of a pathological area, but we describe them differently by using appropriate transmission conditions at the interface between the ablated and the not-ablated area. In the case of RFA, we assume that both intracellular and extracellular potentials are affected, resulting in Kedem-Katchalsky-type conditions at the interface. In contrast, in the case of PFA, we study the static bidomain model and we assume that the thickness of the electroporated (EP) region is small compared with the whole domain and proportional to a parameter ε. Moreover, we assume that within the EP region the intracellular conductivity scales with a factor ε^2. We provide a formal asymptotic analysis at any order by considering an asymptotic expansion of the intracellular and extracellular potentials both outside and inside the EP area. This allows us to derive transmission conditions at the interface for PFA at any order, that read as non-homogeneous boundary conditions for the jump of the extra-cellular potential and its normal derivative, and as Neumann conditions for the intracellular potentials. Moreover, we give a proof of the asymptotic expansion by deriving estimates of H^1- and L^2-norms of the errors. The asymptotic expansion was validated by numerical convergence tests.