Diffusion Reaction Eikonal Alternant Model: Towards Fast Simulations of Complex Cardiac Arrhythmias

Cristian Barrios Espinosa*, Jorge Sánchez, Olaf Dössel, Axel Loewe

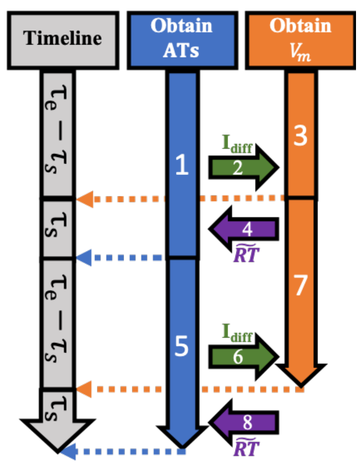
Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany

Introduction: Reaction-diffusion (RD) computer models are suitable to investigate the mechanisms of cardiac arrhythmias but not directly applicable in clinical settings due to their computational cost. On the other hand, alternative faster eikonal models are incapable of reproducing reentrant activation when solved by iterative methods. Single pass (non-iterative) methods to solve the eikonal equation that allow reentrant activation are susceptible to numerical errors in anisotropic conditions.

Methods: The diffusion reaction eikonal alternant model (DREAM) is a new method in which eikonal and RD models are alternated to allow for reactivation (see figure). To solve the eikonal equation, the fast iterative method was modified and embedded into DREAM. First, activation times (ATs) are calculated until a time τ_e is reached. Obtained ATs control transmembrane voltage (V_m) courses in the RD model through an approximated diffusion current (I_{diff}). Meanwhile, repolarization times (RT) are provided back to the eikonal model. V_m is calculated until $\tau_e - \tau_s$ where τ_s is a "safety margin" in time to avoid conflict with following iterations.

Results: For a planar wavefront in the center of a 2D patch, DREAM action potentials (APs) have a small overshoot in the upstroke compared to pure RD simulations (monodomain) but similar AP duration. DREAM conduction velocity does not increase near boundaries or stimulated areas as it occurs in RD. Anatomical reentry was successfully reproduced with the S1-S2 protocol.

Discussion: This is the first time that an iterative method is used to solve the eikonal model in a version that admits reactivation. This method can facilitate uptake of computer models in clinical settings. Further improvements will allow accurately representing even more complex patterns of arrhythmia.



Steps of DREAM