Role of Fiber Orientation and Ionic Heterogeneities to Simulate Chronic Atrial Arrhythmias

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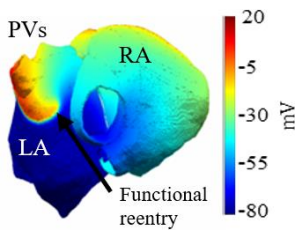
Introduction: Detailed simulations of atrial arrhythmias are a useful tool to identify target treatments for atrial fibrillation (AF) and tachycardia (AT). However, the degree of detail needed in these simulations to truly recreate AF/AT mechanisms in patient-specific anatomies is still unclear. This study assesses the role of fiber direction (FD) and ionic heterogeneities (IH) to reproduce atrial arrhythmias in chronic atrial substrates.

Methods: An atrial 3D anatomy (Krueger et al) including regional-specific FD and IH corresponding to left/right atria, pulmonary veins (PVs), valves and other regions was used. Koivumäki's cellular model and monodomain model were used to simulate cardiac electrophysiology. Three different pro-arrhythmic scenarios, including different degrees of electrical remodeling (persistent to chronic AF) and different stimulation protocols, were simulated in presence and absence of FD and IH, these last as isotropic conduction and homogeneous LA tissue, respectively. The pro-arrhythmic behavior of each configuration was evaluated as the presence of AF/AT maintained by specific atrial regions.

Results: The proposed stimulation protocols and substrates produced different arrhythmic patterns, including AT and AF maintained by functional reentries near the PVs (see Figure). In general, when both FD and IH were considered, all scenarios were pro-arrhythmic with 2 cases with AF maintained by a functional reentry at the septum, and one macro-reentry (AT) around by the PVs (see Table). Removing ionic heterogeneities from simulations produced one scenario to be non-arrhythmic, whereas removing fiber direction did produce non-arrhythmic patterns in 2 out of 3 cases.

Conclusion: Fiber direction and ionic heterogeneities are crucial to reproduce atrial arrhythmic mechanisms in persistent and chronic AF. Their absence reduces the ability to reproduce typical AF and AT patterns at common clinical targets such as the PVs.



	cAF / St1	cAF / St2	pAF / St2
FD / IH	AF at Sep.	AT at PV	AF at Sep.
FD / No IH	AT at PV	AF at Sep.	NA
No FD / IH	AT at MV	NA	NA
No FD / No IH	AT at MV	NA	NA

cAF: Chronic AF; pAF: Persistent AF; St1/St2: Stimulation protocols; FD: Fiber Direction; IH: Ionic Heterogeneities; AT: Atrial Tachycardia; AF: Atrial Fibrillation; PV: Pulmonary veins; Sep: Septum; NA: Non-arrhythmic MV: Mitral Valve