Inducibility Tests of Atrial Fibrillation by Automata-based Efficient Simulations

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Aims: This paper extends a cellular automaton (CA) model for atrial electrophysiology. Integrated in this model is the differentiation of different atrial tissue types within complex geometries. Finally, evaluation of this model's efficacy in predicting chronic AF (cAF) instances across varied conditions is presented herein.

Methods: The CA model, trained initially on limited atrial tissue biophysical simulations, was improved by integrating tissue-specific data and anisotropy (Fig. A). This involved adjusting tissue-specific conduction velocity (CV) and transverse-to-longitudinal scalar parameters, alongside varying diffusivity levels. The CA model was validated under pathological conditions through simulations using both the CA model and a biophysical solver. Detailed volumetric bi-atrial domain simulations were conducted to assess arrhythmia induction, employing a pacing protocol from four different atrial locations (N = 192, S1 = {130, …, 240} ms, Fig. B).

Results: Incorporating anisotropy into the CA model to align with the biophysical model involved adjusting conduction velocity (CV) based on tissue type, considering both longitudinal (CV_L) and transverse (CV_T) components. These adjustments yielded consistent outcomes across different levels of electrical remodeling. In all 192 simulations, the CA model achieved 80% accuracy, 96% specificity, and 45% sensitivity (Fig. C). Additionally, the CA model demonstrated shorter computational times compared to the biophysical solver: speed-ups of 4.7 for 2106 nodes and 64.6 for 284578 nodes.

Conclusion: CA model emerges as an efficient and valid alternative for simulating atrial electrophysiology throughout various stages of AF. It offers a valuable tool for personalized therapy planning through digital twin simulations, thereby paving the way for more targeted treatment strategies.