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Towards Personalized Biophysical Models of Atrial Anatomy and Electrophysiology in Clinical Environments

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Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia. AF can be treated pharmaceutically or cured by catheter ablation. Computational models of the human atria help to understand the biophysical mechanisms leading to AF. Personalization of anatomical and electrophysiological models paves the way to enable patient-specific radio-frequency ablation therapy planning and evaluation.

Methods

We separated the personalization of atrial models into the personalization of electrophysiology, excitation propagation and anatomy. The generalized models in each area were personalized to the patient's pathology group and sub-group and later to the individual patient and to different regions within the patient's atria. A set of distinct anatomical landmarks was used to semi-automatically insert common ablation lesion patterns into a variety of patient-specific models using the fast marching level set shortest path technique. Delayed-enhancement MRI (DE-MRI) was used to image ablation lesions from two patients acutely after the intervention. Information about the ablation scars were transferred onto the patient-specific volumetric, anisotropic geometrical models to evaluate the therapy outcome. An adjusted fast marching level set algorithm was used to simulate the anisotropic and heterogeneous atrial depolarization sequence.

Results

Personalized atrial models can realistically reproduce the atrial activation sequence, which is determined by fast conducting myocardial bundles. Manual adjustment of interatrial conduction routes produced a better match of simulated to measured left atrial activation sequences. Simulation of sinus rhythm in the DE-MRI enhanced model revealed potential gaps in ablation lesions. Simulations on models with different lesion patterns helped to understand the impact of the various lesion patterns on the cardiac function.

Conclusion

Fast simulation of the atrial depolarization on semi-automatically personalized atrial models allowed for model-based ablation therapy evaluation and planning. In the future, such techniques will enable the application of computational models to personalize ablation therapy in clinical practice.

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