Atrial Fibrillation-based Electrical Remodeling in a Computer Model of the Human Atrium

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Atrial fibrillation (AF) is a common cardiac pathology affecting 10% of the older population. AF is characterized by an abnormal rapid and irregular activation. Sustained AF contributes to congestive heart failure, ventricular arrhythmia, cardiac mortality and thromboembolic stroke. Additionally, AF modifies the atrial electrical properties (electrical remodeling) promoting the occurrence and maintenance of AF.

Electrical remodeling includes changes in the L-type calcium as well as the inward rectifier, the acetylcholine regulated and the outward rectifier potassium channels. These effects were integrated in the human atrial model of Courtemanche et al.. Electrical remodeling further includes a decrease in connexin40 expression. This was considered in the conductivity for the utilized monodomain equation calculating excitation propagation. As geometrical model, a 2D rectangle was used. To analyze the bahavior of physiology and remodeling, the action potential duration (APD), effective refractory period (ERP), conduction velocity (CV), wave length (WL) and their restitution curves were investigated. Furthermore, the number of spirals and the power spectrum of the pseudo ECG were analyzed.

APD in tissue was reduced from 322ms to 144ms for remodeling. Similarly, ERP was reduced from 330ms to 103ms. Both effects are due to the ion channel changes. CV was lowered from 755mm/s to 608mm/s mainly based on the conductivity reduction. As the WL is the product of ERP and CV, its reduction is even higher (from 249mm to 63mm) leading to a higher chance of occurrence and maintenance of AF. In the physiological case, no spirals could be initiated because of the long WL. For remodeling, a maximum of 7 spirals were initiated leading to a peak in the power spectrum of 10.32Hz.

The model shows the potential risk of electrical remodeling and can further be used in computational studies of AF treatment planning like RF ablation or drug design.