Control of Electrical and Calcium Alternans on a One-Dimensional Cardiac Cable

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Background: Cardiac alternans is a heart arrhythmia where the action potential duration (APD) and intracellular calcium transient (Cai) can alternate from beat to beat. The T+T- feedback control was previously shown that it can control alternans for map-model and single cell effectively. However, it is not clear if it can also perform effectively for a multi-cellular system.

Aims: The alternans is voltage (V)-calcium (Ca) positive coupling if a large Cai corresponds to a long APD in the same beat and is V-Ca negative coupling if a small Cai corresponds to a long APD in the same beat. In this study, we analyzed the effectiveness of controlling both V-Ca positive and negative coupling alternans using T+T- feedback control for 1D cable of cardiac cells.

Methods: Numerical simulations were performed on the ten Tusscher and Panfilov 2006 action potential model (TP06). During the T+T- feedback control, the basic cycle length (T) at each beat was perturbed with a small pre-set control parameter ε ($\varepsilon << T$). For positive (negative) coupling alternans, T was changed to $T + \varepsilon$ if the APD is longer (Cai is larger) than the previous APD (Cai), and was changed to $T - \varepsilon$ if the APD is shorter (Cai is smaller) than the previous APD (Cai).

Results: It was shown that the feedback control can suppress the positive coupling alternans better than the negative coupling alternans. It was also found that the amplitudes of alternans became smaller if smaller ε were used.

Conclusion: We compared the effectiveness of T+T- feedback control for the suppression of positive and negative coupling alternans on a 1D cable. Since alternans is a precursor to ventricular fibrillation and sudden cardiac death, this work may provide guidance to the development of a better control protocol for cardiac alternans.