Controlling Chaos with Multiphase Pacing

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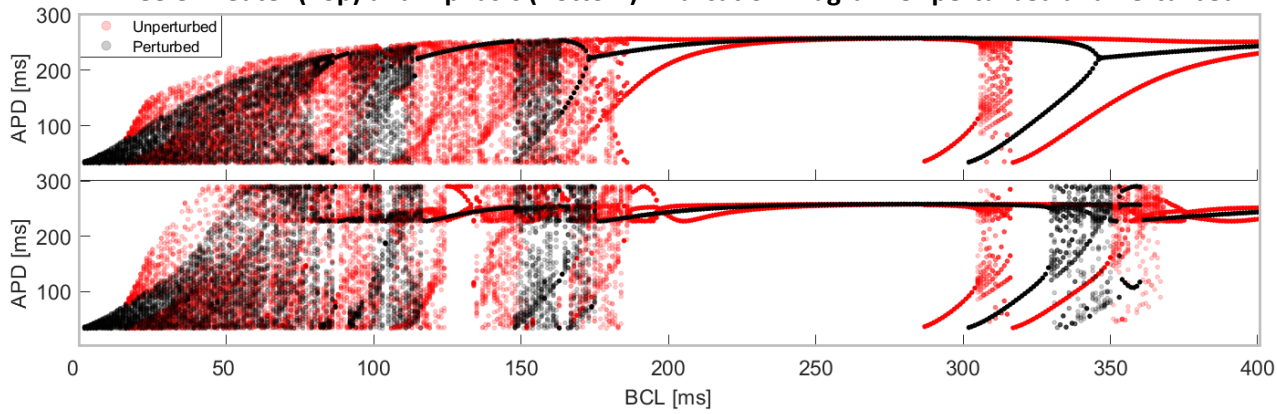
Aims: This study seeks to demonstrate the viability of using periodic multiphase pacing to induce, shift, and terminate chaotic domains and bifurcation points of bifurcation diagrams for single cell cardiac models.

Methods: An action potential duration (APD) restitution map for a single cell cardiac model, such as the Beeler-Reuter and others, are iterated for long periods to construct the corresponding bifurcation diagram. This restitution map is then further iterated with multiphase pacing, in which periodic perturbations are added and subtracted to the pacing cycle length, to determine what effect the perturbations have on the overall structure of the bifurcation diagram. Since these perturbations are small (5 to 10 ms) and oscillate around a base frequency, this base frequency (BCL) is used as our metric.

Results: Most oscillating pacing sequences applied to monotonic cardiac restitution maps produced from models such as Beeler-Reuter not only expand the chaotic regime but also shift bifurcation points to longer periods. For maps such as the Biphasic Beeler-Reuter, oscillating pacing sequences can cause a splitting effect in which the chaotic region and bifurcation points shift and split in opposite directions, to longer and shorter periods. The induced shift can be calibrated by the perturbation as it increases proportional to the perturbation.

Beeler-Reuter (Top) and Biphasic (Bottom) Bifurcation Diagram Unperturbed and Perturbed



Conclusions: The specific perturbation sequences implemented have a large effect on what control possibilities are accessible given an APD restitution map. However, it is clear that simple oscillating perturbations can be used to shift chaotic regimes and bifurcation points to higher or lower frequencies, effectively terminating and inducing chaos and alternans at new cycle lengths. This suggests a robust method that can be applied in experimental procedures directly to cardiac tissue to not only find regions of chaos to study, but more specifically, to develop control of alternans and chaos in the clinic.