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Controllability Analysis of Discrete-map Models of Cardiac Alternans

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An arrhythmia is a disorder in the heart that occurs due to irregular or abnormal heartbeats. There are many types of arrhythmias, some of which are harmless, but a few, including ventricular tachycardia and fibrillation, can be serious or life-threatening. Certain arrhythmias are preceded by electrical alternans, which is a state characterized by beat-to-beat alternation in cellular action potential duration. Cardiac alternans may arise from instabilities in either voltage or intracellular calcium cycling. Although a number of techniques have been proposed to suppress alternans, most have focused on appropriately adding a new ionic current or adjusting the timing of pacing stimuli based on the difference between recent action potential durations rather than affecting intracellular calcium directly. In addition, most of the methods proposed to suppress alternans have been tested using models that do not include calcium-driven alternans. Therefore, it is important to establish a theoretical basis for understanding how control methods may apply when alternans develops via calcium instabilities. In this study, we apply controllability analysis to analyze discrete maps of alternans dynamics in cardiac cells. In particular, we compute ranks of controllability matrices to determine to what extent different control strategies can suppress alternans. Our study provides insight into the feasibility of controlling alternans driven wholly or partially by intracellular calcium instabilities.