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Capacitive memory alters alternans and spontaneous activity in a minimal cardiomyocyte model

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Capacitive memory alters alternans and spontaneous activity in a minimal cardiomyocyte model

The electrical behavior of cardiomyocytes are typically simulated using ideal parallel resistor-capacitor circuit networks. However, recent studies have suggested that non-ideal capacitor circuit elements, in which the current-voltage relationship is governed by a fractional order derivative, may more appropriately model cell membrane properties. These fractional-order dynamics can represent capacitive memory effects in which electrical activity is altered by the membrane potential prior history. Previous work has shown that fractional-order membrane dynamics alters spiking rates and ionic currents in neurons. Here, the effects of capacitive memory are investigated in a cardiomyocyte model using a minimal 3-variable system, modified for fractional-order membrane voltage dynamics. This model was chosen due to its intrinsic lack of memory effects. Fractional-orders from 0.5 to 1 with varying cycle lengths were simulated. We found that decreasing fractional-order shortened action potential duration (APD) and suppressed the pro-arrhythmic beat-to-beat alternation, alternans, at shorter cycle lengths. For fractional orders less than 0.75, spontaneous electrical activity was observed. Memory effects were represented by a hypothetical memory current that acted to suppress alternans at decreasing cycle lengths and generate spontaneous electrical activity at sufficiently small fractional orders. We suggest that capacitive memory serves to alter the incidence of alternans and may play a role in pacemaking.