The Occurrence of Electrical Instability and Reentry due to Regional Increase in Extracellular Potassium Ion Concentration

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ABSTRACT

Ventricular tachycardia (VT) and ventricular fibrillation (VF) are the two most dangerous arrhythmias. Both are related to reentrant electrical activity in the ventricles. Many studies of arrhythmias consider a homogeneous sheet of cardiac tissue. Since normal ventricular myocardium is inhomogeneous and inhomogeneities play an important role in the induction of reentry, we consider a 2D inhomogeneous sheet of myocardium to investigate the effect of a localized inhomogeneity developed at the border between normal and high potassium regions. We used the bidomain model to represent the electrical properties of cardiac tissue and a modified version of the dynamic Luo-Rudy (LRd) model to represent the active properties of the membrane. To investigate the effect of a localized inhomogeneity, the extracellular potassium \([K_e]\) concentration is raised to 10 mM from normal \([K_e]\) (4 mM) on the right half of the tissue. An increase of \([K_e]\) to 12 mM on the right hand side (ischemic area) of the myocardium sheet leads to reentry.

INTRODUCTION & MOTIVATION

VT and VF are the two most dangerous arrhythmias. During VT, ventricles of the heart contract very fast, and during VF ventricles of the heart contract in an asynchronous fashion. Both of these arrhythmias are related to reentrant electrical activity in the ventricles. Most of the studies related to reentry (a self-perpetuating circulating wave front) consider a homogeneous sheet of cardiac tissue. But, it has been known that normal ventricular myocardium is inhomogeneous and inhomogeneities play an important role in the induction of reentrant rhythms in the heart.

Hence we consider a 2D inhomogeneous sheet of myocardium to investigate the effect of a localized inhomogeneity developed at the border between the homogeneous and inhomogeneous region.

METHODS

We used the bidomain model to represent the electrical properties of cardiac tissue and a modified version of the Luo-Rudy (LRd) model to represent the active properties of the cell membrane.

RESULTS & DISCUSSION

The lower left corner of the tissue is first stimulated with a cathodal stimulus (S1) applied at time 100 ms. This stimulus excites an action potential that propagates outward from the electrode. A train of cathodal stimuli are applied from the lower left corner of the tissue with various basic cycle lengths (BCL). At certain BCLs, the spatial heterogeneity created with regional elevation of \([K_e]\) can lead to action potential instability (alternans) in the normal and border regions, and 2:1 conduction block in the ischemic region. We observed the reentry when local heterogeneity in \([K_e]\) is changed from 10 to 12 mM on the right half of the virtual ventricular myocardium sheet.

CONCLUSION & FUTURE WORK

At certain BCL, the spatial heterogeneity can lead to action potential instability and 2:1 conduction block. Sidorov et al. (2011) detected a normally propagating wave front in normal \([K_e]\) region, alternans in the border, and 2:1 conduction block in high \([K_e]\) region. An increase of \([K_e]\) to 12 mM on the right hand side of the myocardium sheet leads to reentry. Our future goals are to find the cause of alternans and to find the mechanism of reentry developed at the border between normal and high \([K_e]\) by considering more realistic ischemic tissue on the right.

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