Cardiac homogeneity despite asynchrony?

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Introduction

Contraction of cardiac muscle fibers (myofibers) is initiated by a propagating wave of electrical depolarization. The use of a 3D finite element model of the heart combining wave propagation and wall mechanics may provide new insights in the interpretation of deformation, following conduction disturbances.

The relation between the moments of depolarization and increase in active myofiber stress (onset of crossbridge formation) in myofibers is not well known. In a mathematical model of the left ventricle (LV) we tested the hypothesis that electromechanical delays (EM-delay) of all myofibers are homogeneously distributed. Computed myofiber strain was compared with reported experimental results.

Material and methods

Figure 1 Left: artist’s impression of the heart. Right: the myofiber action potential [mV] and active stress [kPa] as a function of time. The moment of depolarization ($t_{dep}$) was solved in the eikonal-diffusion equation [1] as a function of position in the cardiac wall. Cardiac mechanics was solved from the momentum equation. Myofiber active stress increase started at the moment of crossbridge formation ($t_{crossbridge}$), and was dependent on time, sarcomere length, and sarcomere shortening velocity.

Results

Figure 2 Patterns of moment of crossbridge formation [ms]. SYNC simulation: unphysiological synchronous ($t_{crossbridge} = 0$ ms). NORM simulation: crossbridge formation following a normal depolarization pattern ($t_{crossbridge} = t_{dep}$), which is similar to measurements of depolarization [3].

Conclusions

The simulations predicted either an unphysiological nonuniform contraction pattern during physiological depolarization, and a physiological contraction pattern during unphysiological synchronous depolarization. We reject the hypothesis of homogeneous EM-delay. The new hypothesis is that EM-delay times are heterogeneously distributed, such that a contraction in a normal heart is more synchronous than depolarization. This hypothesis is highly intriguing and urges experimental validation.

References: