Accuracy of Estimates of Cardiac Action Potential Durations from Extracellular Waveforms Simulated by the Bidomain Model

Simone Scacchi, Piero Colli Franzone, Luca F Pavarino* and Bruno Taccardi

Dept of Mathematics, University of Milano, Milano, Italy

Objectives. Maps depicting the distribution of action potential durations (APD) on epicardial, endocardial and transmural surfaces provide important information for understanding normal and abnormal cardiac electrical activity. The goal of this work is to provide an extensive quantitative analysis of the accuracy level of the cardiac activation - recovery interval (ARI) distributions, obtained from extracellular electrogram markers, in comparison with a gold standard based on transmembrane APD distributions. Both heterogeneous and pathological (ischemic) conditions of the myocardial tissue are considered.

Methods. The analysis is based on large-scale 3D numerical simulations of the anisotropic Bidomain system coupled with the Luo-Rudy I membrane model. Activation and recovery sequences are simulated in myocardial blocks with homogeneous, heterogeneous and ischemic intrinsic cellular properties. ARI maps are determined from activation and repolarization time markers computed from either unipolar electrograms or from an alternative technique based on hybrid monophasic action potentials, obtained as the potential difference between a permanently depolarized site and an exploring site.

Results. The results show that on the whole the extracellular ARI and HMAP distributions considered are reliable and estimate the gold standard APD distributions with low relative mean discrepancies ($<= 2.1\%$) and good correlation coefficients ($>= 0.9$) in tissues with transmural heterogeneity. However, both ARI distributions can yield locally inaccurate APD estimates in regions where the curvature of the repolarization front changes abruptly (e.g near front collisions) or is negligible (e.g. where repolarization proceeds almost uniformly across fibers).

Conclusions. Even though the recovery maps based on extracellular repolarization time markers are very well correlated with maps of transmembrane recovery distributions, the associated ARI maps can have local inaccuracies and be weakly correlated with maps of APD distributions. In particular, both extracellular repolarization time markers generally underestimate the transmural repolarization time dispersion and consequently ARI measures underestimate the transmural APD dispersion.