In-silico study of the cardiac arrhythmogenic potential of biomaterial injection therapy

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ABSTRACT

Biomaterial injection treatment to improve the cardiac function of hearts with ischemic heart failure (HF) has shown many positive outcomes in preclinical applications. However, the influence of this therapy on the behavior of action potential propagation has not been clearly elucidated. In this work, we developed computational models of swine hearts to study the electrophysiological vulnerability associated with biomaterial injection therapy. Action potential propagation was simulated using a monodomain approach and geometrical models of high-resolution MRI and diffusion tensor-MRI data from normal, untreated, and treated hearts. The regional restitution properties of each heart were evaluated by constructing a density function distribution of the action potential duration (APD) restitution curve while account for the arrangement of biomaterial injections, infarcted zones (IZ) and gray zones (GZ) within the myocardium. In addition, a comparative analysis of the ventricular fibrillation (VF) dynamics for every heart was done by measuring the number of filaments formed after wave brake. Finally, a preliminary sensitivity analysis to measure the influence of biomaterial conductivity was made in a VF scenario. Our results show that injection of biomaterials does not alter the regional distribution of the APD restitution curve. Further, biomaterial injections do not seem to affect the VF dynamics arising in hearts with ischemic HF. The sensitivity analysis of the biomaterial conductivity shows that biomaterial injection seems not to change VF dynamics substantially in treated hearts, compared with untreated hearts. This work represents a proof-of-concept that high-performance computer simulations of the heart can be used to gain insights, in silico, of biomaterial injection treatments and their arrhythmogenic potential.