Electromechanical Modelling of the Myocardium using XMR Interventional Imaging

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Introduction & Aim: Myocardial electrophysiology study (EPS) is carried out prior to procedures such as radio frequency ablation or biventricular pacing for heart failure. Under x-ray fluoroscopic guidance, the procedures are often lengthy and there is considerable delivered x-ray dose. Electrophysiological mapping systems such the EnSite system have made some progress to facilitate EPS procedures. We are undertaking a programme of XMR guided EPS procedures using the EnSite system. Cardiac MR imaging can be used to obtain anatomical and functional information prior to and after the procedure. We have previously reported a technique to register MR and x-ray images obtained in the XMR environment. In the current work we apply our technique to EPS procedures with the aim to validate our electromechanical model of the heart. We present the initial results from our first case.

Method: Our XMR facility consists of a Philips Intera I/T 1.5T MR system and a Philips BV Pulsera mobile cardiac x-ray system. The patient (male, age 68) was catheterised under local anaesthetic to assess the optimal location for biventricular pacing. Initially, MR imaging was performed. A volume scan of the heart was acquired using an SSFP sequence (3 phases, 256x256 matrix, 120 slices, resolution=1.48x1.48x1.0mm, TR=3.2ms, TE=1.6ms, flip angle=45°) and CSPAMM spiral tagged images were acquired in both short and long axis views (35 phases, 256x256 matrix, 9 slices SA & 5 slices LA, resolution=1.76x1.76x12.0mm, TR=13.0ms, TE=1.1ms, flip angle=30°, tag spacing=6mm). The patient was then transferred to the x-ray system and an EPS was carried out. The EnSite system used a balloon catheter and a roving catheter that were placed in the left ventricle of the patient. The system created a surface model of the chamber and interpolated the measured electrical activity onto this surface. Biplane x-ray images were acquired with the catheters in place and registered to the MR data. The left heart was segmented from MR data. Using the registered x-ray images, the location of the catheters was found in the coordinate system of the segmented MR data. The EnSite surface model was registered to the segmented MR data using the known location of the catheters in these two coordinate systems. It was then deformed to fit the segmented MR data. The tagged MR images were analysed using a non-rigid registration technique to quantify the myocardial motion. Therefore, we were able to combine the anatomical, electrophysiological, and motion data in the same coordinate system. Having achieved this, the measured electrical data were used to

initialise our electrophysiological model of the myocardium to generate a simulation of electrical depolarisation based on the reaction-diffusion equations of FitzHugh-Nagumo.

Results: Figure 1a shows the biplane x-ray images. Figure 1b shows the reconstructed position of the catheters within the segmented MR anatomy. Figure 1c shows the EnSite surface model registered to the MR anatomy with the progression of depolarisation for three cardiac phases. Figure 1d shows the simulated electrical depolarisation for the same three phases. Figure 1e shows the EnSite surface deformed to fit the segmented MR data. Finally, figure 1f shows the myocardial deformation computed from the tagged MR data for three phases.

Conclusions: We have proposed a method to integrate anatomical, electrophysiological, and myocardial motion data for patients undergoing EPS. We have presented our initial simulation results for myocardial depolarisation. We are currently applying our electromechanical coupling model to this data to simulate the myocardial contraction and compare this to the measured motion from the tagged MR images. Our registration technique will aid in EPS procedure guidance, and using our electromechanical model we will be able to simulate the outcome of different pacing strategies.