Modelling the Cardiac Electromechanical Activity for Integration of Electrophysiological Studies with MR

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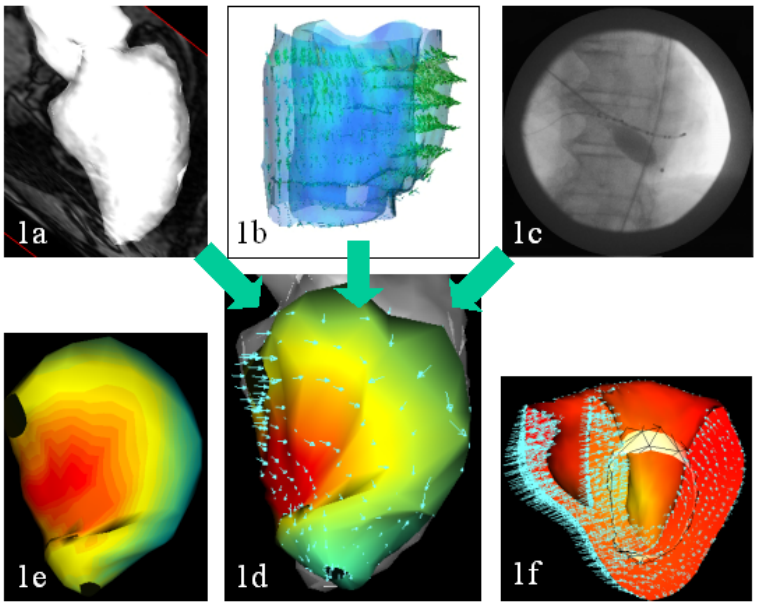
Introduction & Aim. MR imaging provides a unique way to observe cardiac function through detailed anatomical description and motion information. However, electrophysiological studies (EPS) are conducted under x-ray fluoroscopic guidance, which make the procedures often lengthy due to the lack of geometrical information and results in a considerable delivered x-ray dose. New 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, as well as help the guidance during intervention. 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. Such a model offers an integration tool including anatomical, mechanical and electrophysiological information in the same framework, and make possible the simulation of different pathologies and intervention procedures.

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 72) 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. Then the ESI surface fitted to the anatomical MR can be deformed according to the motion extracted from the tagged MR. Therefore, we were able to combine the anatomical, electrophysiological, and motion data, and visualize it on the same surface. 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. Then the simulation of the contraction is possible through an electromechanical coupling, and the result can be compared with the motion extracted from the tagged images.



Results

Figure 1a shows the segmented MR anatomy in the MR image, Figure 1b shows the myocardial deformation computed from the tagged MR and Figure 1c shows one of the biplane x-ray images. Then Figure 1d presents the integrated anatomical, motion and electrophysiological information on the same surface, with the color representing the value of the extra-cellular potential and the light blue arrows showing the displacement from tele diastolic position, computed from the tagged MR images.

Figure 1e shows the simulated electrical isochrones from the model, initiated with the patient measures and Figure 1f presents the electromechanical model of the myocardium, deforming through the simulated contraction, also initiated from the electrophysiological measures. The black mesh represents the ESI measures location, and the blue arrows the simulated displacement.

Conclusions. We have proposed a method to integrate anatomical information, myocardial motion data and electrophysiological measures for patients undergoing EPS. We have presented our initial simulation results for myocardial depolarisation and contraction. We are currently comparing this to the measured motion from the tagged MR images. Our registration technique will aid in EPS procedure guidance, and using our electromechanical model will open new possibilities for the simulation of pathologies and the intervention planning, for instance through the simulation of the outcome of different pacing strategies.