XMR – A Novel Strategy for Guiding Pulmonary Vein Ablation

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Introduction & Aim: The recent emergence of hybrid X-ray and MR imaging systems (XMR) has opened up new interventional guidance strategies for cardiovascular catheterisation procedures. We have developed a technique based on optical tracking to register MR and X-ray images of the same patient obtained using the sliding table XMR system configuration. This allows the real-time overlay of registered MRI derived cardiovascular anatomy onto live X-ray fluoroscopy images and the reconstruction of the position of catheters seen during X-ray fluoroscopy in this anatomy. The aim of our on-going programme is to augment a variety of cardiac catheterisation procedures by providing real-time XMR guidance. Cardiac electrophysiology (EP) interventions are often prolonged and require precise catheter positioning. Therefore, we have focussed the use of our guidance system on these procedures. Our system has been used to guide 13 EP procedures to date. 10 of these have been pulmonary vein (PV) isolations for the treatment of atrial fibrillation and we use these to illustrate our guidance system in this abstract.

Methods:

XMR System Description: The XMR interventional suite at King's College London (Guy's Hospital Campus) comprises of a 1.5 T cylindrical bore MR scanner (Philips Intera I/T) and a mobile cardiac X-ray set (Philips BV Pulsera). Patients can be moved in less than 60 seconds between the two systems using a specially modified sliding table.

Modifications for Image Registration: MR and X-ray image registration is achieved by a combination of calibration and real-time tracking. The X-ray c-arm and the X-ray table are optically tracked by a Northern Digital Optotrak 3020 using infrared emitting diodes. The sliding table is tracked by the MR system software while docked to the MR scanner and becomes part of the X-ray table when docked to the X-ray system.

System Calibration: Calibration of the system involves imaging a specially designed acrylic calibration object. This object consists of a half cylinder that can accept 120 interchangeable fiducial markers that can be visualised with both MR and X-ray imaging, and located using an Optotrak pointer. The calibration object was imaged using a T1-weighted MR sequence and then 50 tracked X-ray views were acquired for a range of c-arm orientations. The fiducial markers were automatically located in all the images and this data was used to compute the relationship between the MR scanner and the X-ray system, and the perspective projection parameters of the X-ray system. All X-ray images acquired could be corrected for geometric distortion using a distortion model. Once the system was calibrated, it was possible to register any MR image acquisitions to X-ray image acquisitions.

Real-Time Guidance: During interventions the guidance system can provide a real-time MR anatomy overlay onto X-ray images. The guidance software runs in the Microsoft Windows environment on a workstation with a dual monitor display. One monitor is used to display the control interface and the second monitor displays the image overlay. During fluoroscopy the system acquires X-ray images and computes the registration matrix from the tracking data at 10 frames per second and updates the overlay display at 3 frames per second.

Pulmonary Vein Isolation Cases: The protocol for the 10 PV isolation procedures was as follows. The patient was placed on the sliding table and transferred to the X-ray side. Local anaesthesia and sedation were administered. Sheaths were inserted to gain vascular access. Internal cardioversion was carried out if the patient was in atrial fibrillation. The patient was then transferred over to the MR side. A gadolinium enhanced MRA scan capturing the left atrial anatomy was performed. The patients were then transferred to the X-ray side. The MR scan was exported to the guidance system workstation and processed to generate the left atrial anatomical surface. The ablation catheter used was a 16-electrode helix catheter (Revelation Helix, Cardima, CA, USA). This catheter was deployed into the left upper, left lower, and right upper PV orifices in turn and ablation was performed. During the procedure the guidance system displayed the left atrial surface overlaid onto the X-ray images of the catheter. Before each ablation, biplane X-ray images were acquired of the catheter and the 3D location of the catheter was reconstructed and displayed in the MR derived anatomy.

Results: Figure 1 shows an example of guidance system overlay when the delivery catheter was placed in the left lower PV. Figures 2 shows an example of the reconstructed location of the helix catheter in all three PVs.

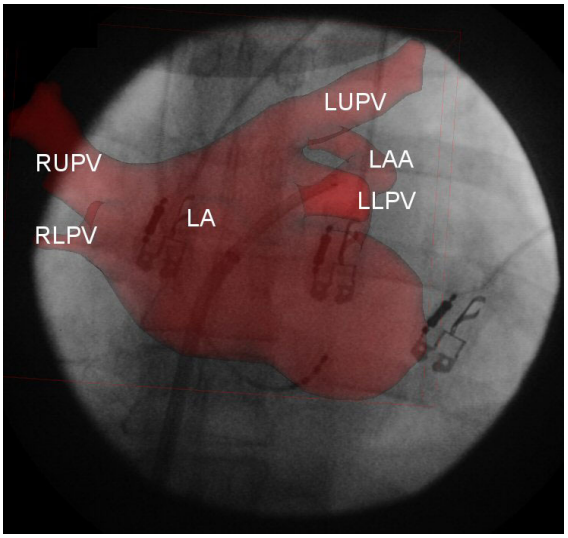

Figure 1: Guidance system overlay display showing the delivery catheter in the left lower pulmonary vein. LA=left atrium, LAA=left atrial appendage, PV=pulmonary vein, LU=left upper, LL=left lower, RU=right upper, RL=right lower.

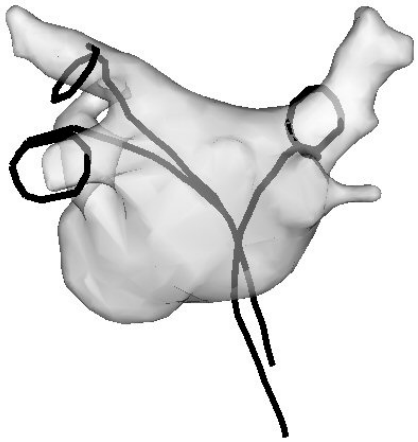

Figure 2: The reconstructed location of the helix catheter in the patient anatomy during each ablation.

Conclusion & Future Work: We have developed a real-time guidance system that allows the visualisation of combined MR and X-ray images during cardiovascular interventions in the XMR environment. The system has been used to guide 10 cases of pulmonary vein isolation. The advantages offered over a conventional approach include the ability to visualise the left heart anatomy allowing easier guidance of catheters into the pulmonary veins. The placement of the helix ablation catheter could be assessed using the anatomical overlay and also using the catheter reconstructions. It was also possible to select working X-ray views without the administration of X-ray dose by moving the c-arm until the anatomical overlay was suitably positioned. Our guidance system should reduce procedure time for EP interventions and reduce the delivered X-ray dose. In our on-going programme we aim to improve our system by addressing the problems of cardiac and respiratory motion and by improving the X-ray projection calibration by modelling X-ray gantry sag, which contributes a significant error in the registration.