MR-Guided Electrophysiology Ablations

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Introduction

Cardiac arrhythmias are a leading health problem, afflicting millions of people world-wide. The field of cardiac electrophysiology (EP) has grown rapidly in recent years as a means of studying and treating some of the most common forms of arrhythmia, such as atrial fibrillation and ventricular tachycardia. Electrical catheters inserted into the heart are used for electrical mapping, pacing, and radio-frequency ablation[1].

Simultaneous guidance of the catheters and visualization of anatomy presents a significant challenge to the electrophysiological interventionist. The current practice is to visualize both anatomy and electrical data through point-by-point acquisition of electromagnetically-tracked catheters. Because information on catheter position is unregistered with any anatomical images, the resulting visualization depicts the anatomy poorly and is not superimposed on any MR, CT, or ultrasound images. In some procedures, such as rf ablations, several hours are spent just to map the anatomy, without acquiring electrical data. It is desirable to have real-time images of the anatomy superimposed with catheter positioning information and electrical activity measurements.

We have developed a system that integrates electrophysiology procedures with MRI[2]. With this system MRI is used to visualize both anatomy and the instantaneous position of catheters[3]. Catheter positions obtained using active MR tracking strategies are combined with electrical measurements and superimposed on a surface-rendered 3D MR image set. Using this system we have performed a number of electrophysiology procedures on healthy and infracted pigs under MR guidance, including voltage mapping in the left ventricle, right atrium, and left atrium, as well as ablation procedures in the right and left atrium. We have performed RF ablation isolation of the left pulmonary vein in pigs, a procedure very common in treatment of atrial fibrillation, as well as ablation of the atrial-ventricular node.

Materials and Methods

The system has been described in previous work[2]. Electrophysiology data is acquired using a CardioLab 7000 Electrophysiology unit. The amplifier unit is placed in the scan room with filtering of radio frequency currents to prevent interference with the MR scanner. Surface EKG data is used to trigger the acquisition of electrical voltage measurements from an EP catheter that has been designed for MR compatibility (St. Jude Medical, Minnetonka, MN).

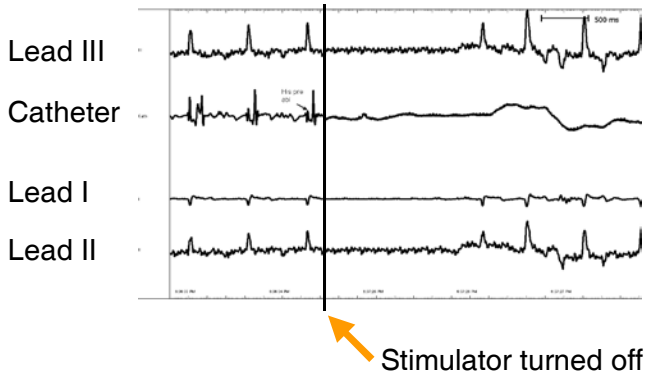
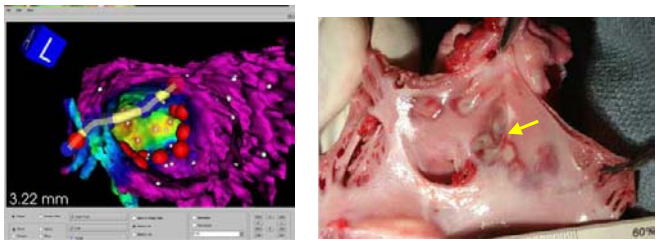


Figure 1: Surface and internal electrocardiograms after ablation of the AV node. The lack of electrical activity in the left ventricle after the stimulator is turned off ('Catheter' trace) confirms the AV nodal ablation.



(a) (b)

Figure 2: (a) Electrical voltage map and ablation points (red spheres) at the ostium of the left pulmonary vein of a healthy pig. The catheter is shown as the yellow cylindrical object. (b) Photograph of excised heart showing lesions applied around ostium (yellow arrow).

Positional data from the MR tracking coils and the electrical measurements from the catheter electrodes are sent to a data integration computer, which displays the ECG data for the cardiologist. This data is combined with surface renderings of the anatomy based on pre-acquired 3D MRA data to display the devices and the anatomy in real time in three dimensions on EM-shielded displays next to the scanner.

Results and Discussion

Validation of the MR-guided mapping procedure has been performed in pigs by comparison with the current clinical standard, Biosense CARTO EP[2]. The left ventricles of five infarcted pigs were mapped under both systems in the same day, with excellent agreement. Successful RF ablation procedures have been performed in both atria, including right isthmus ablation and atrio-ventricular nodal ablations (a procedure commonly performed prior to pacemaker implantation). In addition, we have performed RF ablation isolation of the left pulmonary vein, a common treatment for atrial fibrillation.

Figure 1 shows a graph of the electrocardiogram after ablation of the AV node. The vertical line indicates the point where the stimulator, placed in the right ventricle, was turned off. The 2nd trace from the top shows electrical activity measured from an EP catheter in the left ventricle. The lack of electrical activity after the stimulator was turned off confirms the AV nodal ablation

Figure 2a shows a screenshot of the intra-procedural visualization of the ostium of the left pulmonary vein. Positions of applied lesions are marked with red spheres. Figure 2b shows the excised heart and the lesions that have been applied around the pulmonary vein.

These experiments demonstrate the feasibility of performing EP mapping and ablation under MR guidance. MR offers advantages of superior anatomical visualization, the ability to image infarcts, the ability to assess lesion damage [4,5], and the potential to monitor temperature increases to guide the therapy. Such benefits could be a major improvement in EP ablation procedures.

References

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