MR-Guided Electrophysiology Interventions

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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. Catheters with multi-polar electrical ports are inserted into the heart for voltage mapping, pacing, and radio-frequency ablation[1].

Simultaneous guidance of the catheters and visualization of anatomy presents a significant challenge to the electrophysiologist. 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 anatomical MRI or CT images, the resulting visualization depicts anatomy poorly. In some procedures, such as RF ablation, significant time is required to map the anatomy prior to ablation. It is therefore desirable to have registered images (pre-acquired and real-time) of the anatomy superimposed with catheter positioning information and electrical activity measurements.

We developed a system that integrates EP procedures with MRI. With this system MRI is used to visualize both anatomy and the instantaneous position of catheters[2]. Catheter positions obtained using active MR tracking are combined with electrical measurements and superimposed on a surface-rendered 3D MR image set, which is acquired immediately before the interventional procedure, and thus registered to it. Using this system we have obtained voltage maps of the left ventricle for seven infarcted pigs and one normal pig. On five pigs, we also obtained maps using the current clinical standard, the CARTO (Biosense-Webster) electromagnetic catheter tracking system.

Materials and Methods

Figure 1 shows a simplified diagram of the MR-guided electrophysiology system. Electrophysiology data is acquired using a CardioLab 7000 Electrophysiology unit. The amplifier unit is placed in the scan room with appropriate filtering of radio frequency currents to prevent interference with the MR scanner. Surface ECG 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).

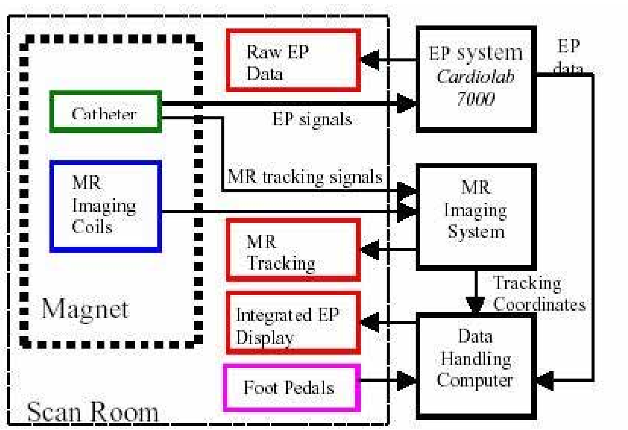

Figure 1: diagram of MR-guided EP system

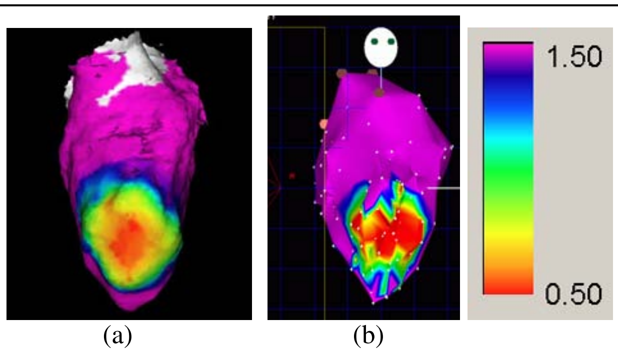

Figure 2: Electrical voltage maps of left ventricle of an infarcted pig under MR-guided EP (a) and Biosense CARTO EP (b). The color scale represents millivolts peak-to-peak signal on the internal ECG signal. The figure shows good qualitative agreement between the two mappings.

Positional data from the MR tracking coils and the electrical measurements from the catheter electrodes are sent to a data-handling computer, which displays the ECG data for the cardiologist. The data handler computer is also used to evaluate the data with electrophysiology algorithms such as peak-to-peak voltage and timing intervals. In addition, the data is combined with surface renderings of the anatomy based on pre-acquired 3D MRA data to display the device and the anatomy in real time in three dimensions.

The scanner is under in-room control of the cardiologist, with foot pedals to control the EP data acquisition. In-room displays provide multiple views of the data to the cardiologist, both in-slice-representations and in a 3D rendered display. Navigation can be performed against any pre-acquired image set. In this study, MRA, cine-MRI, and 3D-MDE images were acquired prior to mapping, enabling the cardiologist to identify the infarct and immediately begin mapping around it without prior searching.

Results and Discussion

The left ventricles of five infarcted pigs were mapped under both the CARTO and MRI-EP systems in the same day. Figure 2 shows a comparison in one experiment. The color scale shows peak-to-peak voltage measurements of the internal ECG signal, in millivolts. The infarcted areas are seen as areas of depressed voltage. The figure shows good agreement between the Biosense maps and the MR-guided maps. In addition to mapping, we performed RF ablation under MR guidance while simultaneously imaging in real time, with no significant degradation in image quality.

These experiments demonstrate the feasibility of performing EP mapping and ablation under MR guidance. MR offers advantages of superior anatomical visualization, selective infarct imaging, the ability to assess lesion damage [3,4], and the potential to monitor thermal dose to guide the therapy. Such benefits could be a major improvement in EP ablation procedures.

References

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