MR Guided Electrophysiology Using Active MR Tracking

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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 to study and treat some of the most common forms of arrhythmia, such as atrial fibrillation (AF) and ventral tachycardia (VT). 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 the anatomy presents a significant challenge to the electrophysiological interventionist, particularly when traditional X-ray methods are employed. One current practice is to visualize both the anatomy and electrical data through point-by-point acquisition of electromagnetically-tracked catheters. Because information on catheter position is unregistered with anatomical images, the resulting visualization depicts the anatomy poorly and is not typically 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. This system is used to both visualize anatomy and to locate catheters in real-time using active MR tracking [2]. Catheter position data is combined with electrical measurements and superimposed on a surface-rendered 3D MR image. Point source MR tracking is acoustically quiet, obtaining catheter locations at rates as high as 30 fps, without employing rapid MR imaging for device localization [3].

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 (GE Healthcare, Milwaukee, WI). The amplifier unit is placed in the MR magnet room with appropriate 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 compliance (St. Jude Medical). The catheter contains three MR tracking coils, with one at the tip of the catheter to locate the point of EP data acquisition.

The position of the tracking coils and the electrical measurements on the catheter are sent to a data integration computer, which displays the electrophysiology data for the cardiologist to evaluate (Figure 2). The software developed provides some analysis of the data, enabling extraction of various quantities for mapping, such as peak-to-peak voltage, and various time delays within the cardiac cycle. As data points are acquired, electrical data is converted to a color scale, combined with real-time spatial information from the MR tracking coil at the tip of the catheter, and displayed on a surface rendering of a pre-acquired MR data set for the cardiologist.

The scanner is under in-room control of the cardiologist, with foot pedals to control the EP data acquisition and to turn the MR tracking sequence on and off. In-room displays show the real-time tracking data, the electrophysiology data, and the combined surface rendering of the anatomy and the EP measurements.

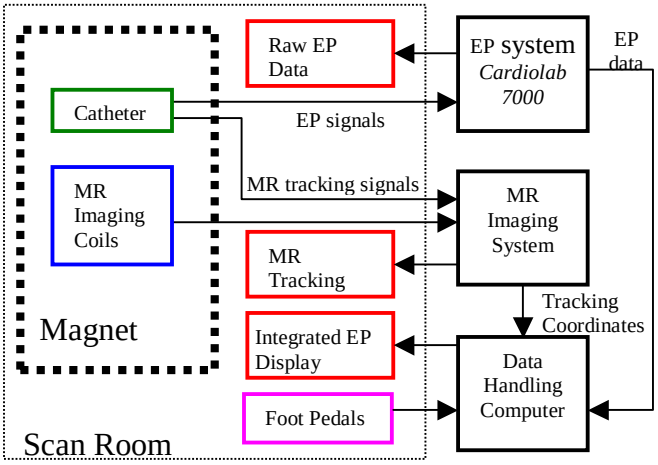

Figure 1: Diagram of the MR-guided electrophysiology system.

Results and Discussion

We have successfully integrated the MRI and the electrophysiology systems for simultaneous acquisition and display. Gradient interference with the surface EKG leads was minimized with a commercial physiological monitoring system (Magnitude CV, InVivo Research, Orlando, FL). The MR tracking acquisition is not expected to interfere significantly with the intra-cardiac EKG signal, as the electrodes are extremely close together and the leads are adjacent to one another as they exit the magnet.

Figure 2: Data integration software for displaying electrophysiology data for the cardiologist. The above traces are signals from a cardiac simulator that were detected in the magnet room with the EP system.

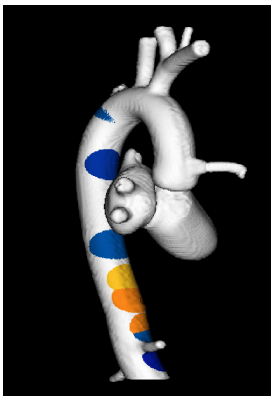

Figure 3: Phantom image of a segment of the aorta. The colored points represent EP data acquired from a cardiac signal simulator, but placed using active MR guidance of an MR EP catheter.

Figure 3 shows an image taken on an aortic phantom in which generated EKG signals have been acquired by the CardioLab 7000 system, combined with the catheter tracking information, and displayed on the surface rendering using in-house software (Cardiac++). Visualization of the EP information is performed by associating points on the surface of the anatomy with the nearest acquired EP point, out to a maximum radius that is configurable by the cardiologist. Both displays were presented to the cardiologist in real-time in the scan room and without latency.

Future experiments on animal models will demonstrate the capability of this system to perform *in-vivo* measurements within the heart.

References

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