MR-Guided Endocardial Local Activation Time Map During Programmed Stimulation

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Introduction. In cardiac electrophysiology (EP), the use of electroanatomic mapping (EAM) systems allow for localization of reentry pathways and foci of tachyarrhythmias[1]. In the case of scar-related arrhythmias, voltage maps and/or activation maps are created to accurately identify the location of scars and area of the isthmus (slow conduction region). Previous studies have identified the benefits of combining MR imaging and catheter guidance with electrophysiology tools[2-4]. The majority of these studies have presented MR-guided voltage maps; in this study, we present initial experience of ventricular endocardial local activation time (LAT) mapping during programmed stimulation, extending the capacity of our previously presented system[5].

Methods. We performed experiments on 6 porcine models (3 complete studies, 3 partial studies). Images were acquired with a 1.5T GE Signa system (GE Healthcare, Milwaukee, WI, USA). Short-axis breath-held SSFP cine images were obtained to cover the entire right ventricle (RV) and left ventricle (LV) with the following parameters: BW 62.5 kHz, flip angle 45°, TR/TE 3.7/1.1 ms, field of view (FOV) 210 mm, acquisition matrix 224x160, slice thickness 6 mm and 20 phases over the heart cycle. EP measurements were performed using a prototype Bridge™ EP Recording System with two Vision™ MR conditional catheters (Imricor Medical Systems, Burnsville, MN): this EP system has an integrated stimulator for pacing and each catheter has 4 electrodes and three tracking coils. Visualization of tracking catheters was performed using Vurtigo[6] and MR-guided activation EP data was processed off-line using Matlab. The pacing catheter was placed in the RV, while the recording second catheter was maneuvered in the left ventricle (LV). For consistency the annotation of the local activation time was established at the maximum peak after the onset of the bipolar electrogram. Controlled conventional three-dimensional endocardial LAT maps were also acquired from bipolar recordings using a CARTO XP system (Biosense Webster, Diamond Bar, CA).

Results. MR-guided EAM of the LV was successful both in sinus rhythm and with pacing. The MR-guided LAT map agreed well with the CARTO LAT map. During the MR study, the MR-compatible EP mapping catheter was navigated to endocardial positions in the LV for direct electrical characterization of activation times across several regions. Pacing with myocardial contraction was achieved and performed at a 400ms cycle length or 150 BPM at 3mA (for the pig shown in Fig 1). In the CARTO map the earliest activation point originates in the apical-septal and mid-inferoseptal regions, because pacing was performed from the RV. The last recorded point is in the basal-lateral region of the LV. Similarly, in the MR-Guided map, earliest activation times also originate in the apical-septal region and the latest in the same approximate region as the CARTO.

Discussion. Some commercial EAM systems include options to register their LAT maps to previously acquired MR (or CT) images; however, our system with near simultaneous imaging and EP recording provides a solution that minimizes registration errors or errors due to changes in the physiology of the patient. During our studies, some discrepancies were observed in association with the loss of myocardium contact, loss of myocardium capture during pacing or catheter damage due to irreversible mechanical torsion (which negatively impacted the ability to navigate the catheter in different regions). In all these cases the points recorded under these condition were discarded. Differences between activation times for the two systems were probably caused by a slight change of position of the reference pacing catheter during transportation to the MR suite.

Conclusion. Real time correlation of functional anatomical and electrical information during cardiac electrophysiological study will ultimately lead to better outcomes in complex cardiac EP procedures. This study presents an important aspect of feasibility of EP in live MR suite, specifically the creation of local activation time maps that has not been shown before under direct MRI guidance. The integration of MR data into EP studies should yield more efficient and effective identification of potential arrhythmia-inducing reentry locations.
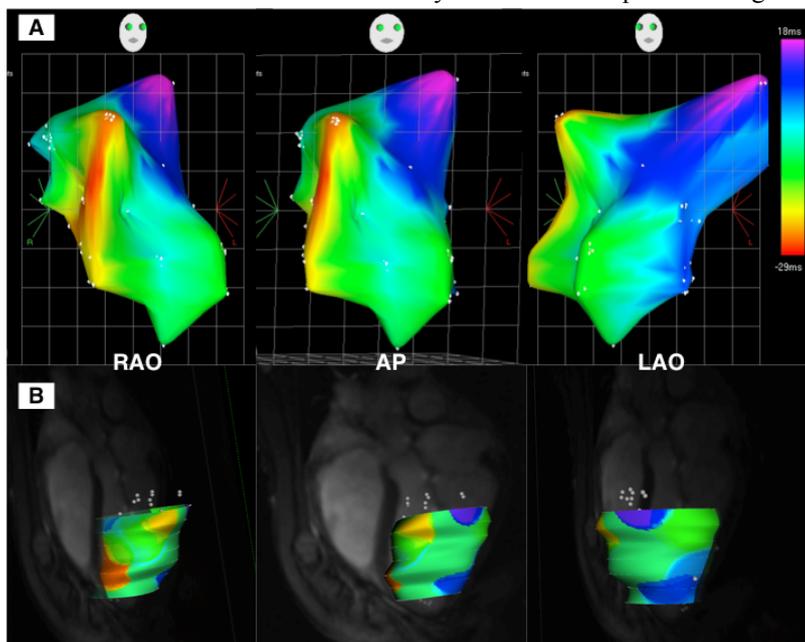

Figure 1 – A) Local activation time map using CARTO in RAO (Right Anterior Oblique) AP (Anterior Posterior) LAO (Left Anterior Oblique) views. B) MR-guided EP system activation map in the same animal. Points and anatomical images are all acquired in the same frame reference. And the LV endocardial surface was segmented from 2D MR images.

References. 1. Aliot EM, et al. EHRA/HRS Expert Consensus on Catheter Ablation of Ventricular Arrhythmias. Heart R 2009;6(6):886-933. **2.** Dukkipati et al. Electroanatomic mapping of the left ventricle in a porcine model of chronic myocardial infarction with magnetic resonance-based catheter tracking. Circ 2008;118(8):853-862. **3.** Nazarian S et al. Feasibility of Real-Time Magnetic Resonance Imaging for Catheter Guidance in Electrophysiology Studies. Circ 2008;118(3):223. **4.** Schmidt E, et al. Electro-Anatomic Mapping and Radio-Frequency Ablation of Porcine Left Atria and Atrio-Ventricular Nodes using Magnetic Resonance Catheter Tracking. Circ Arr Electrophysiol 2009. **5.** Oduneye SO, et al. MR-Guided Electrophysiology System for Activation and Pace Mapping in Left Ventricle. ISMRM 2010 May; Stockholm. #4122. **6.** Pintilie S, et al. VURTIGO: Visualization Software for Real-time, Image-guided Interventions. mirrortransactnetau 2009.