

Assessment of the Transmural Extent of Acute Atrial Lesions using Electrogram Amplitude vs. LGE-MRI

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Introduction: Radiofrequency (RF) ablation of the left atrium (LA) and pulmonary vein ostia has become a clinically acceptable therapy for atrial fibrillation (AF) [1,2]. Yet reported success rates of the procedure vary significantly with AF recurrences ranging from 25-60%. Currently, this interventional procedure is performed in an electro-physiology (EP) suite under X-ray fluoroscopy. Electro-anatomical mapping (EAM) guidance and reduction in local tissue electrogram (EGM) amplitude remains a widely used, albeit indirect, method to assess the LA wall injury. With the advent of improved MRI sequences to visualize post ablation scar [3,4], MRI offers a promising method for assessment of the transmural extent of LA wall injury. Real-time (RT) MRI [5] has been previously tested to guide atrial ablation [6] and perform EAM and EGM recordings at 1.5 Tesla magnetic fields [7]. In this work, we illustrate that EGM recordings cannot be reliably used to distinguish transmural atrial lesions from superficial endocardial injuries. Late gadolinium enhancement (LGE) MRI may be better suited to discriminate these injuries.

Methods: Three animal experiments were performed to compare EAM and EGM recordings acquired in the EP suite with similar recordings acquired in a 3-Tesla MRI suite and compare them with respect to extent and transmurality of ablation lesions visualized by LGE-MRI. The protocol of the study was approved by the local IACUC. RF ablations were performed in the right atrium (RA) of adult minipigs (weight 25-32 kg) in the EP suite (Artis zeego, Siemens Healthcare, Forchheim, Germany) using a clinical guidance system (CARTO XP, Biosense Webster, Diamond Bar, CA). All RF lesions were created with identical power settings of 30 Watts using the Stockert RF generator (Biosense Webster, Diamond Bar, CA). EAM and EGMs were recorded in the EP suite using the CARTO system. The animals were then transported to the MRI suite and received MRI scans consisting of localizers, followed by a contrast-enhanced, 3D MR angiography (contrast dose of 0.15 mmol/kg, injection rate of 0.15 ml per second, Multihance, Bracco Diagnostic Inc., Princeton, NJ). 3D LGE imaging was performed at multiple time points after injection of contrast agent to identify the regions of the RA ablated in the EP suite. It has previously been shown that early LGE images of acute atrial lesions show a no-reflow effect [8, 9], so LGE images were acquired as soon as 10 minutes post contrast injection. The RA endocardial surface and the lesions created in the EP-suite were segmented from the MRA and LGE images (Seg3D, SCI Institute, Salt Lake City, UT), respectively and the resulting segmentations loaded into a custom navigation prototype based on the Interactive Front End (IFE) platform (Siemens Corporate Research, Princeton, NJ) to facilitate catheter navigation. EAM and EGMs were recorded in the MRI suite using a BioPac system (BIOPAC Systems Inc., Goleta, CA), with a novel 7F, 3T MR-compatible, mapping catheter (SurgiVision Inc., Irvine, CA) both of which were connected with MRI compatible interface circuits, custom built for 3T magnetic fields (SurgiVision Inc., Irvine, CA). All MR imaging was performed using the body and spine array Tim coils at 3T using a Siemens MAGNETOM Verio scanner (Siemens Healthcare, Erlangen, Germany) with RT-MRI guidance using custom prototypes based on the IRTTT real time pulse sequence and IFE navigation software (Siemens Corporate Research, Princeton, NJ). At the end of the study, the animals were euthanized and their hearts extracted for macroscopic examination.

LGE images of the RA were acquired using a 3D respiratory navigated, inversion recovery prepared GRE pulse sequence with TE/TR=1.4/3.0 ms, flip angle of 14°, bandwidth=780 Hz/pixel, FOV=240x240x110 mm, matrix size=192x192x40, 10% oversampling in slice encoding direction, voxel size=1.25x1.25x2.5 mm, phase encoding direction: left to right, fractional readout=87.5%, partial Fourier acquisition: 87.5% in phase-encoding direction and 90% in slice-encoding direction. Inversion pulse was applied every heart beat and fat saturation was applied immediately before data acquisition. Data acquisition was limited to 15% of RR cycle and was performed during RA diastole. Typical scan time for LGE study was 3-5 minutes depending on heart rate and respiration rate.

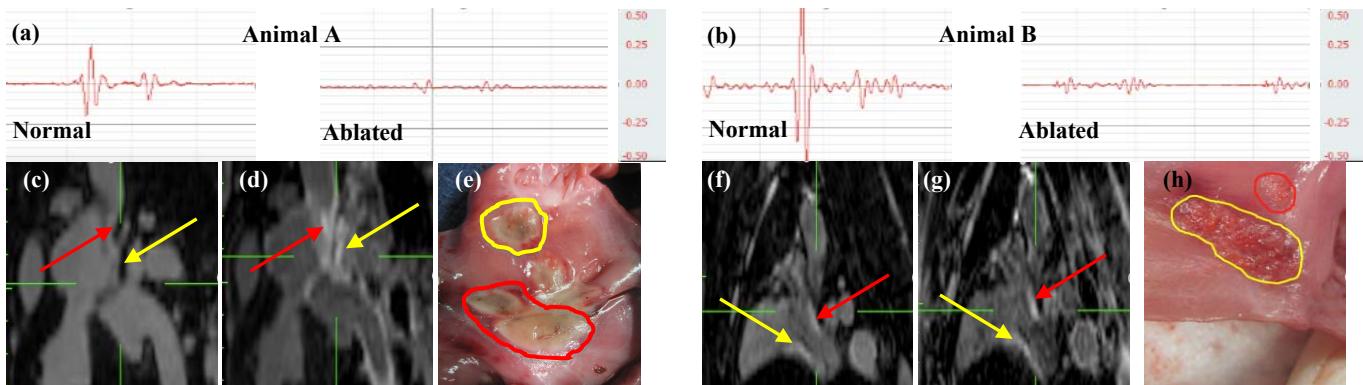


Figure 1. (a) & (b) EGM recorded under MRI guidance from normal tissue in the RA where no ablation was performed, followed by the EGM from ablated region indicated by the yellow arrow, from two different animals A and B; (c) & (d) LGE images acquired 10 mins and 33 mins post contrast injection respectively of animal A; (f) & (g) LGE images acquired 13 mins and 30 mins post contrast injection respectively of animal B; (e) & (h) Ex-vivo images of the extracted RAs of animals A and B, respectively.

Results: Similar reduction in EGM amplitude was observed in the ablated regions of the RA in the recordings made in the EP and MRI suites. However, two distinct types of atrial wall injuries were identified based on serial LGE-MRI imaging. In the first type, lesions showed an enhanced periphery with a dark central region (no-reflow phenomenon) in early LGE-MRI (Fig. 1c) that showed enhancement in later LGE-MRI (30 minutes) scans (Fig. 1d). The second type of lesions enhanced very early in the serial LGE-MRI scans and stayed enhanced in later LGE-MRI scans as well (Fig. 1f, 1g). Ex-vivo gross pathology (Fig. 1e, 1h) revealed that the first type of injury was very prominent and transmural while the second type of lesion was just superficial injury on the endocardial surface of the RA wall.

Conclusion/Discussion: Our preliminary results indicate that EGM amplitude reduction (measured in both EP and MRI labs) may not be a reliable indicator of the transmural extent of atrial lesion. Serial LGE-MRI, on the other hand, can clearly distinguish between transmural and superficial atrial injuries. Thus, serial LGE-MRI has the potential to become a very useful tool to assess lesions immediately following ablation.

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Acknowledgements: The authors thank Sheila Mann for the animal preparation and monitoring of animal vitals during the entire study. This study was supported in part by SurgiVision Inc., Siemens Healthcare, Ben B. and Iris M. Margolis Foundation and NIH grant P41-RR12553-10.