

Assessment and Completion of RF Ablation for the Treatment of Atrial Fibrillation using Real-Time MRI Guidance

S. Vijayakumar^{1,2}, E. G. Kholmovski^{1,2}, R. Ranjan^{2,3}, G. Vergara^{2,3}, J. Blauer^{2,4}, G. Payne^{1,2}, N. Volland^{1,2}, K. Vij⁵, G. Gardner^{2,4}, P. Piferi⁵, K. Johnson^{2,3}, L. Pan⁶, K. Kirchberg⁶, R. MacLeod^{2,4}, C. J. McGann^{2,3}, and N. F. Marrouche^{2,3}

¹UCAIR, Department of Radiology, University of Utah, Salt Lake City, Utah, United States, ²CARMA Center, University of Utah, Salt Lake City, Utah, United States, ³Department of Cardiology, University of Utah, Salt Lake City, Utah, United States, ⁴SCI, University of Utah, Salt Lake City, Utah, United States, ⁵SurgiVision Inc., Irvine, California, United States, ⁶Center for Applied Medical Imaging, Siemens Corporate Research, Princeton, NJ

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]. One of the main hurdles of this interventional procedure is the inability to adequately evaluate tissue injury caused by RF ablation during the procedure itself, resulting in recurrence of AF following ablation and the need for repeat procedures [3]. Repeat procedures are typically performed at least three months after the original ones, requiring the patient to endure new femoral vein access, sedation and hospitalization. With the advent of MRI sequences to visualize post ablation scar and assess treatment outcome [4,5], MRI offers a promising method to assess these RF ablations. Real-time (RT) MRI [6] is becoming a useful tool for interventional applications and has been previously tested for atrial ablation as well [7,8]. Introduction of electrophysiology-MRI (EP-MRI) laboratories makes it possible to perform ablation procedure in the EP suite, transport patient to the MRI suite to assess ablation injury and complete the procedure under RT-MRI guidance if necessary. **In this work, we have studied the feasibility of this EP-MRI workflow of RF ablation for AF treatment that may help reduce the need for repeat ablation procedures.**

Methods: Three experiments to create RF lesions in the right atria (RA) of adult minipigs (weight 25-32 kg) were performed according to protocols approved by the local IACUC. Catheter access was by means of a 12F introducer sheath placed in the right femoral vein to enable the introduction of either a conventional EP (Biosense Webster, Diamond Bar, CA) or a custom-made 3-Tesla MR-compatible ablation catheter (SurgiVision Inc, Irvine, CA). All ablations were performed using the Stockert RF generator (Biosense Webster, DiamondBar, CA). Ablation in the MRI suite was performed using a novel, 7F, 3-Tesla MR-compatible, mapping and ablation catheter (SurgiVision Inc, Irvine, CA). The catheter, equipped with tracking coils for navigation/MR guidance, was connected to the RF generator using MR compatible interface circuits (SurgiVision Inc, Irvine, CA), custom built for 3-Tesla magnetic field. All MR imaging was performed using the body and spine array Tim coils at 3-Tesla using a Siemens MAGNETOM Verio scanner (Siemens Healthcare, Erlangen, Germany) with RT-MRI guidance provided using custom prototypes based on the IRTTT real time pulse sequence and the Interactive Front End (IFE) navigation software (Siemens Corporate Research, Princeton, NJ).

RF ablation in the RA was first performed in the EP suite to create two distinct regions (labeled A and B) in the atrial wall separated by a gap of about 10 mm. The animals were then transported to the MRI suite. The MRI study began with the 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 of the same volume was performed to identify the regions of the RA ablated in the EP-suite (Figure 1A and 1B). The RA endocardial surface and the lesions created in the EP-suite were segmented from the MRA and LGE images, respectively and the resulting segmentations were loaded onto the IFE platform for RT catheter guidance (Figure 1C and 1D). Ablation in the MRI suite was performed for 3 minutes at 20 Watts of RF energy, with the goal of filling the gap between lesions A and B. Contrast agent (0.15 mmol/kg, Multihance) was administered again and LGE imaging performed to confirm that the gap between lesions A and B was ablated. The parameters for the different scans were as follows: RT-MRI: 2D GRE sequence with resolution=1.8x2.4x4 mm, TR/TE=3.5/1.5 ms, flip angle=12°, acceleration R=2, 4 frames per second; MRA: respiratory navigated, ECG gated, 3D GRE with resolution=1.25x1.25x2.5 mm, TR/TE=2.8/1.3 ms, flip angle=20°, R=2; LGE: respiratory navigated, ECG gated, inversion recovery prepared GRE with resolution=1.25x1.25x2.5 mm, TR/TE=2.9/1.4 ms, flip angle=15°, R=2. At the end of the study, the animal was euthanized and the heart extracted for macroscopic examination.

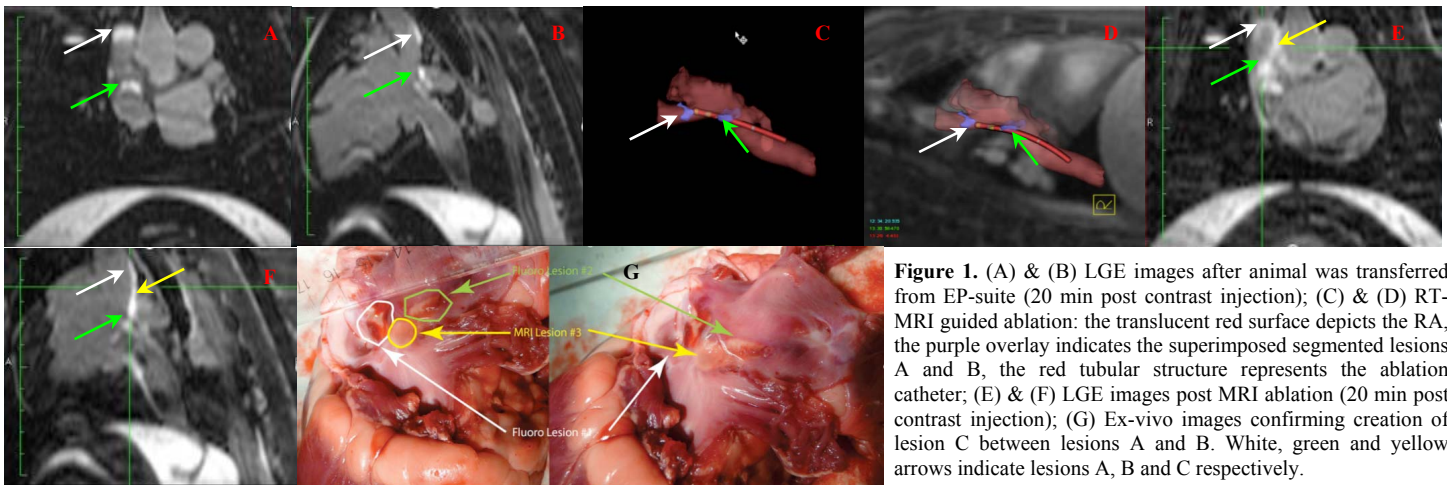


Figure 1. (A) & (B) LGE images after animal was transferred from EP-suite (20 min post contrast injection); (C) & (D) RT-MRI guided ablation: the translucent red surface depicts the RA, the purple overlay indicates the superimposed segmented lesions A and B, the red tubular structure represents the ablation catheter; (E) & (F) LGE images post MRI ablation (20 min post contrast injection); (G) Ex-vivo images confirming creation of lesion C between lesions A and B. White, green and yellow arrows indicate lesions A, B and C respectively.

Results: In all three studies, the gap between the lesions A and B was detected by LGE-MRI and successfully ablated under RT-MRI guidance. Ex-vivo gross pathology validated the agreement between images and the lesions created in the EP and MRI suites. Figure 1 shows typical images acquired during one study. Lesions A and B were created under fluoroscopy guidance in the EP suite and Lesion C in the middle was created under MRI guidance. The ex-vivo images (Fig. 1G) confirm the presence of three lesions. Time between transporting the pig from the EP suite to the MRI suite and acquisition of contrast enhanced MRA and 3D LGE images was approximately 30 minutes. Segmentation of the RA and the lesions took about fifteen minutes and RT-MRI guided catheter navigation to position the catheter in the right location in the RA about ten minutes. Therefore, within an hour of finishing ablation in the EP suite, the electrophysiologist has the ability to assess the lesions produced in the EP-suite and finish the procedure (fill in any gaps in ablation) under RT-MRI guidance.

Conclusion/Discussion: In this work, we have shown that RF ablation procedures can be assessed by MRI and completed under RT-MRI guidance if necessary. LGE-MRI provides a robust means of evaluating the location of acute RF lesions, thus providing a confirmation of effectiveness that is not available using conventional approaches like endocardial voltage mapping. RT-MRI and associated devices and software provide a viable means to carry out additional lesions based on this MRI based evaluation.

References: 1. Haissaguere M et al. *N Engl J Med* 1998; 339:659-66. 2. Cappato R et al. *Circ*. 2005; 111:1100-5. 3. Lellouche N et al. *J Cardiovasc Electrophysiol* 2008; 19:599-605. 4. Peters D et al. *Radiology* 2007; 243:690-5. 5. McGann CJ et al. *JACC* 2008; 52:1263-71. 6. Guttman M et al. *J Magn Reson Imaging*. 2008; 28:538-42. 7. Vijayakumar S et al. *ISMRM* 2010, 285. 8. Schmidt E J et al. *Circ Arrhythm Electrophysiol* 2009; 2:695-704.

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