

Application of blood pool contrast agent to visualize atrial lesion formation during RF ablation procedure

Eugene G. Kholmovski^{1,2}, Sathya Vijayakumar^{1,2}, Ravi Ranjan^{2,3}, Josh Blauer^{2,4}, Nelly Volland^{1,2}, Gene Payne^{1,2}, Michael Guttman⁵, Pete Piferi⁵, Chris J. McGann^{2,3}, and Nassir 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, ⁴Department of Bioengineering, University of Utah, Salt Lake City, Utah, United States, ⁵MRI Interventions Inc., Irvine, California, United States

Introduction: Atrial fibrillation (AF) is the most common cardiac rhythm disturbance affecting more than 5 million people in North America and Europe. Catheter-based radio-frequency (RF) ablation (RFA) is effective in symptomatic, drug refractory AF [1,2]. However, reported success rate of the procedure is relatively low: 40-75%. The main causes of AF recurrence after RFA are tissue recovery and gaps in desired ablation patterns [3]. The extent of LA wall injury cannot be accurately evaluated with conventional electro-physiological (EP) measurements. Introduction of integrated EP-MRI suites allows assessment of extent of the LA wall injury and validation of tissue destruction intermediately through the procedure, and performing targeted re-ablation in acute settings if it is required. It was shown that late gadolinium enhancement (LGE) MRI can be used to reliably discriminate between permanent and transient LA wall injuries [4,5]. Fast clearance of conventional contrast agents used for LGE-MRI makes them less useful in setting when LGE-MRI should be performed multiple times during the interventional procedure. Blood pool contrast agents such as Ablavar (Lantheus Medical Imaging Inc., N. Billerica, MA) have longer clearance time making them attractive candidates to be used in such procedures. However, no prior work has been done to investigate this approach. In this study, we examine the applicability of the blood pool contrast agent Ablavar for visualization of acute atrial lesions.

Methods: Two experiments to create RF lesions in the right atria (RA) of adult minipigs (weight 51 and 58 kg) and visualize them using Ablavar based LGE-MRI were performed according to protocols approved by the local IACUC. RF lesions were created under real-time (RT) MRI-guidance using a novel, 8F, 3-Tesla MR-compatible, irrigated, temperature sensing, mapping and ablation catheter (MRI Interventions Inc., Irvine, CA). All ablations were performed using the Stockert RF generator (Biosense Webster, Diamond Bar, CA) with a power of 30W for 30-60 seconds. MR imaging was performed at 3-Tesla Verio scanner (Siemens Healthcare, Erlangen, Germany) with RT-MRI guidance provided by custom prototypes based on the IRTTT pulse sequence and the Interactive Front End (IFE) navigation software (Siemens Corporate Research, Princeton, NJ). Imaging protocol included contrast enhanced MRA (dose of 0.12 ml/kg, injection rate of 0.05 ml/sec, Ablavar), RT-MRI, and 3D LGE imaging. LGE scan was repeated at different time points after each ablation to find how soon after ablation lesion formation can be detected by Ablavar based LGE-MRI. Time interval between contrast agent injection and ablations was at least 10 minutes to achieve steady-state concentration of contrast agent in blood. Some ablations were performed as late as 1.5 hours after the injection. Additional injection of contrast agent (dose of 0.12 ml/kg) was administered 3 hours after initial one. At the end of the study, the animal was euthanized and the heart was extracted for macroscopic examination.

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=20°, 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°. Two different protocols were used for ECG-gated 3D LGE-MRI: a) region-of-interest (ROI: 6 slices around the catheter tip) scan: inversion recovery prepared GRE with resolution=1.25x1.67x4.0 mm, TR/TE=3.2/1.5 ms, flip angle of 14°; b) whole heart (WH) scan: inversion recovery prepared GRE with resolution=1.25x1.25x2.5 mm, respiratory navigated, TR/TE=3.1/1.4 ms, flip angle of 14°.

Results: Visualization of acute atrial lesions is feasible using the blood pool agent Ablavar. The lesions became visible in LGE images as soon as 3-7 minutes after ablation. This time interval is related to rate of uptake of the contrast agent in injured tissue. Typical Ablavar based LGE images acquired at different time points after the ablation are shown in Fig. 1. Long period of steady-state concentration of blood pool agent in blood allowed acquisition of LGE images with the same value of inversion time during long time interval (see Fig. 2). This feature can be very useful in interventional studies because no time will be wasted for repeated acquisitions of TI-scout sequence. Lesion dimensions evaluated from LGE-MRI were in good agreement with results of ex-vivo examination. Ablavar based LGE demonstrated enhancement mainly in the ablated regions, as opposed to enhancement in the ablated regions and cardiac structures with fibrous tissues (e.x. aorta, valves, and so on) as was observed in conventional LGE-MRI. Additional benefit of blood pool agent was improved blood-myocardium contrast in real-time GRE sequence.

Discussion and Conclusion: Feasibility of visualization of acute atrial lesions using LGE-MRI with the blood pool contrast agent Ablavar was demonstrated in animal studies. Our results show that acute atrial lesion can be visualized as soon as 3 minutes after RF ablation and stays visibly stable for up to 3 hours after the injection of contrast agent. Ablavar based LGE-MRI shows more distinct enhancement predominantly in the ablated regions and not so much in fibrous tissues.

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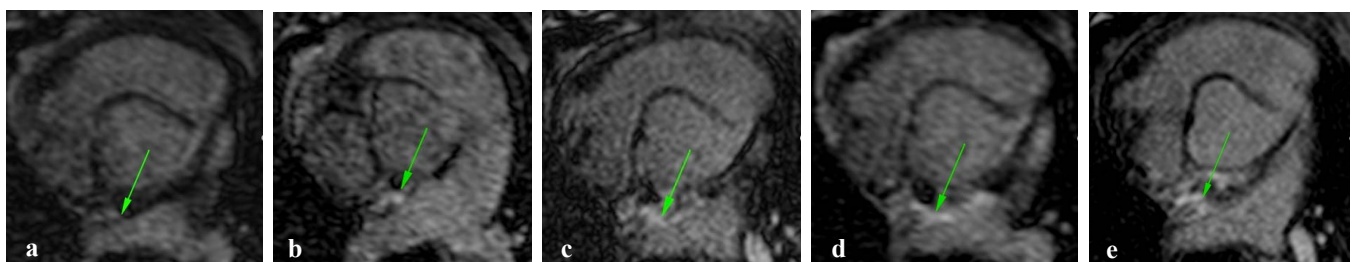


Figure 1. Ablavar-based LGE images acquired before (a) and at different time points after ablation: (b) 3 mins, (c) 12 mins, (d) 18 mins, (e) 57 mins. Green arrows indicate RA lesion. Images (a-d) were acquired using region-of interest LGE-MRI scan, image (e) is from whole heart LGE-MRI scan.

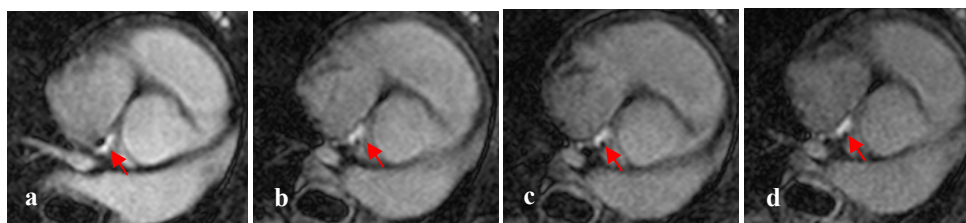


Figure 2. Ablavar-based LGE images of acute atrial lesion acquired at different time points after contrast injection: (a) 35 mins, (b) 115 mins, (c) 145 mins, (d) 190 mins. Red arrows indicate RA lesion created 15 minutes after contrast injection. The images were acquired using whole heart LGE protocol with the same value of inversion time.