Characterization of acute atrial lesions by late gadolinium enhancement MRI

E. G. Kholmovski[1,2], S. Vijayakumar[1,2], C. J. McGann[2,3], J. Blauer[2,4], R. Ranjan[2,3], G. Vergara[2,3], G. Payne[1,2], N. Volland[1,2], R. MacLeod[2,4], and N. F. Marrouche[2,3]

[1]UCAIR, Department of Radiology, University of Utah, Salt Lake City, Utah, United States, [2]CARMA Center, University of Utah, Salt Lake City, Utah, United States, [3]Department of Cardiology, University of Utah, Salt Lake City, Utah, United States, [4]SCI Institute, University of Utah, Salt Lake City, Utah, United States

Introduction: Atrial fibrillation (AF) is the most common cardiac rhythm disturbance affecting more than 5 million people in North America and Europe. Pulmonary vein isolation procedure performed in electro-physiology (EP) suite using radio-frequency (RF) ablation is effective in symptomatic, drug refractory AF. Yet, reported success rates of the procedure vary significantly with AF recurrences ranging from 25-60%. The transmural extent of LA wall injury at the time of ablation is difficult to assess with conventional electro-physiological measurements. With the introduction of EP-MRI suites, patients may be transported into the MRI suite immediately post ablation to assess the LA wall injury using MRI. Late gadolinium enhancement (LGE) [1,2] and double inversion recovery (DIR) prepared T2-weighted (T2w) fast/turbo spin echo (FSE/TSE) and HASTE [3-6] have been proposed to evaluate acute LA wall injury. It was found that enhancement (edema) detected by DIR T2W scans extends beyond the regions subjected to RF energy [7]. In immediately post-ablation studies, LGE images demonstrate heterogeneous appearance of LA wall in the ablated regions [7,8]. Some areas demonstrate hyper-enhancement while other areas have minimal enhancement (no-reflow phenomenon). It was also found that the appearance of acute LA lesions in LGE images changes with time after contrast injection. In this study, we examine the evolution of atrial lesions in LGE imaging with time after contrast injection and compare it with lesion measurements from excised atria.

Theory and 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. All RF lesions were created with identical power settings of 30 Watts using the Stockert RF generator (Biosense Webster, Diamond Bar, CA). At the end of the ablation procedure in the EP suite, each animal was moved to the MRI suite. The time lapse between the end of ablation procedure in the EP suite and the animal in the MRI suite was less than a half hour. MR imaging was performed using a Siemens MAGNETOM Verio scanner (Siemens Healthcare, Erlangen, Germany). Imaging protocol included contrast enhanced MRA (dose of 0.15 mmol/kg, injection rate of 0.15 ml/sec, Multihance, Bracco Diagnostic Inc., Pronceton, NJ),) and 3D LGE imaging. LGE scan was repeated at different time points after contrast injection.

LGE images of RA were acquired using a 3D respiratory navigated, inversion recovery prepared GRE pulse sequence with TE/TR=1.4/3.1 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. Inversion pulse was applied every heart beat and fat saturation was applied immediately before data acquisition. Data acquisition was limited to 15% of cardiac cycle. At the end of the study, the animal was euthanized and the heart extracted for macroscopic examination.

Results: Typical LGE images of ablated RA regions acquired at different time points after contrast injection are shown in Fig. 1. Appearance of ablated RA region in LGE-MRI images changes dramatically with time after injection of contrast agent. On earliest LGE-MRI, injured region is hypo-intense (no-reflow, Fig. 1a). This region will be referenced as original no-reflow further in the text. Later, the periphery of this no-reflow region starts enhancing inward (to lesion center) and outward (Fig. 1b, 1c). After about a half hour post injection, the outer enhancement starts diminishing but the inward expansion of enhancement continues until the entire no-reflow region is enhanced (Fig. 1d). In later LGE-MRI, enhancement is mainly restricted to the original no-reflow region (Fig. 1e). Figure 2a illustrates the dependence of areas of no-reflow and enhancement on time after injection. The plots indicate that size of injury (no-reflow + enhancement) detectable by LGE-MRI changes significantly with time after injection. At earlier LGE-MRI scans, majority of enhancement occurs outside the original no-reflow (Fig. 2b). At later LGE-MRI scans, enhancement is mainly in the original no-reflow. Figure 3 shows a high correlation between both, no-reflow region from earliest LGE-MRI scan and area of enhancement from the latest LGE-MRI scan and the lesion size from measurements on excised right atria respectively.

Discussion and Conclusion: Animal studies were performed to study visualization of acute atrial lesions by serial LGE-MRI. It was found that LGE images demonstrate heterogeneous appearance of atrial wall in the regions subjected to RF energy. This serial LGE-MRI detects two distinct enhancement patterns in ablated regions of atrial wall. Lesion core identified by no-reflow in early LGE and enhancement in very late LGE has very slow contrast dynamics, whereas the regions around the lesion core (edema) have relatively fast contrast dynamics. This obvious difference in contrast dynamics can be exploited to discriminate permanent injury from transient ones. High correlation between lesion measurements made ex-vivo and the original no-reflow or very delayed enhancement shows that LGE-MRI acquired at the right time after contrast injection can be a reliable predictor of permanent scar.

Acknowledgments: This study was supported in part by SurgiVision Inc., Siemens Healthcare, Ben B. and Iris M. Margolis Foundation.

References: [1] Peters D, et al., Radiology 2007;243:690-5. [2] McGann CJ, et al., JACC 2008;52:1263-71. [3] . Vijayakumar S. et al., JCMR 2009;11:214. [4] Knowles BR et al., ISMRM 2009, 487. [5] Peters DC et al., ISMRM 2009, 4433. [6] Kholmovski EG et al., JCMR 2010;12:P97. [7] Kholmovski EG et al., ISMRM 2010, 410. [8] McGann CJ, et al., ISMRM 2010, 588.

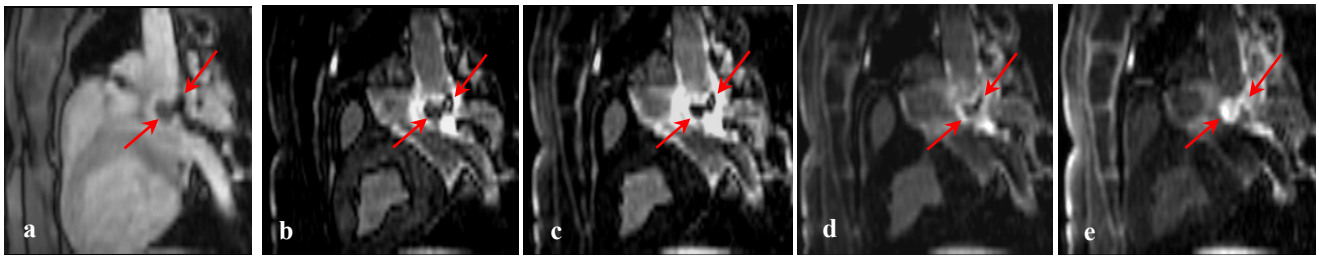

Figure 1. LGE images of RF ablated RA acquired at different time points after contrast injection: (**a**) 5 mins, (**b**) 18 mins, (**c**) 25 mins, (**d**) 37 mins, (**d**) 78 mins. Red arrows indicate two RA lesions.

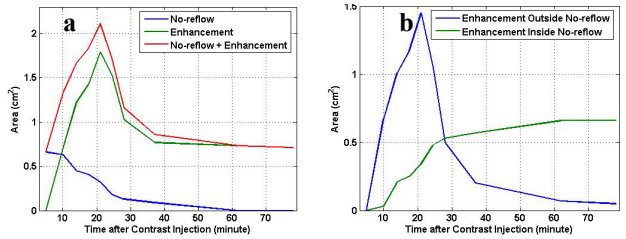

Figure 2. (**a**) Dependence of RA injury area detectable by LGE-MRI on the time after injection. (**b**) Time dependence of enhancement distribution between the original no-reflow and the surrounding region.

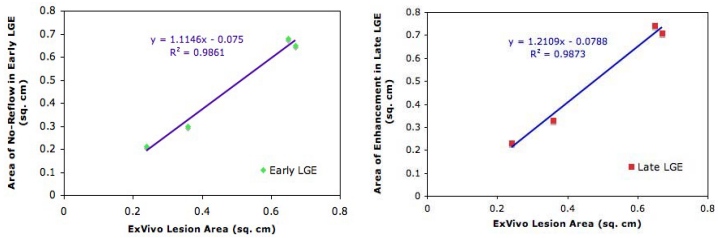

Figure 3. Correlation between area of lesion from ex-vivo measurements and (**a**) no-reflow area in early LGE-MRI, (**b**) enhancement area in late LGE-MRI.