Acute Assessment of Radiofrequency Ablation Cardiac Lesions by Non-Contrast MRI

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Introduction: Atrial fibrillation (AF) is the most common cardiac arrhythmia affecting more than 5 million people in North America and Europe. Pulmonary vein isolation (PVI) procedure performed in electro-physiology (EP) suite using radio-frequency (RF) or cryo ablation is effective in symptomatic, drug refractory AF. Yet, reported success rates of the procedure vary significantly with AF recurrences ranging from 40-75%. The transmural extent of LA wall injury at the time of ablation is difficult to assess with conventional electro-physiological measurements. Development of MRI-guided EP procedures for AF and VT ablations requires robust MRI techniques for intra-procedural evaluation of acute cardiac ablations. Late gadolinium enhancement (LGE) [1,2] and double inversion recovery (DIR) prepared T2-weighted (T2w) fast/turbo spin echo (FSE/TSE) and HASTE [3-5] have been proposed to evaluate acute cardiac ablations. It was found that enhancement (edema) detected by DIR T2W scans extends beyond the ablation regions. In immediately post-ablation studies, LGE demonstrates heterogeneous appearance of LA wall in the ablated regions [6]. Some areas demonstrate hyper-enhancement while other areas have minimal enhancement (no-reflow phenomenon). Furthermore, the appearance of acute cardiac lesions in LGE images changes with time after contrast injection [7]. All these observations and requirement of contrast injection for LGE-MRI make DIR T2w techniques and LGE-MRI barely applicable for MRI-guided EP procedures requiring repeated intra-procedural assessment of cardiac ablations. In this study, we examine T1 and T2 characteristic of acute cardiac lesions and demonstrate that non-contrast T1-weighted technique can be used to visualize acute cardiac RF lesions.

Methods: Eight experiments to create RF ablation lesions in cardiac chambers of adult canines (n=8, weight 25-37 kg) were performed according to protocols approved by the local IACUC. RF lesions were created by ThermoCool catheter (Biosense Webster, Diamond Bar, CA) with identical power settings of 30 Watts for 30 seconds. At the end of the ablation procedure in the EP suite, each animal was moved to the MRI suite. The time la The T1w lesion characterization compared well with more traditional LGE-MRI pse between the end of ablation procedure and the animal in the MRI suite was less than an hour. MR imaging was performed using a 3 Tesla Verio scanner (Siemens Healthcare, Erlangen, Germany). Imaging protocol included T1, T2, and T2* mapping, DIR T2w TSE, 3D T1w and T2*w imaging, followed by contrast injection (0.15 mmol/kg, MultiHance (Bracco Diagnostic Inc., Princeton, NJ)) and post-contrast 3D T1w and 3D LGE. T1w and LGE scans were repeated at different time points after contrast injection. Non-contrast 3D T1w imaging was performed twice with one hour interval between scans to validate repeatability of lesion imaging.

Non-contrast T1w images of the heart were acquired using a 3D respiratory navigated, saturation recovery prepared GRE pulse sequence with TE/TR=1.4/3.1 ms, flip angle of 12^o, TI=400 ms, FOV=240x240x110 mm, matrix size=192x192x40, voxel size=1.25x1.25x2.5 mm. Saturation pulse was applied every heart beat and fat suppression was applied immediately before data acquisition. 4 animals were euthanized at the end of the MRI study and the hearts extracted for macroscopic and histological examination. The other 4 animals were imaged at 1 week, 2 weeks, 1 and 2 months after ablation. 3-month after initial ablation, the animal was re-ablated and MRI study was repeated for these 4 animals. At the end of this study animal was euthanized and the heart extracted for macroscopic and histological examination.

Results: Representative T1 and T2 maps of acute ventricular lesions are shown in Fig. 1a-b. Presence of two distinct regions (lesion core and surrounding edema) in ablation area was observed in T1 maps. Lesion core has lower T1 value than T1 of the surrounding edema. Analysis of magnetization recovery curve for lesion cores demonstrated deviation from mono-exponential function. This observation can be explained by the presence of two compartments in lesion core: short and long T1 compartments. We hypothesize that long T1 corresponds to edema and short T1 corresponds to irreversibly destroyed tissue. Based on these observations, non-contrast T1w technique for assessment of acute RF was developed. The technique utilizes saturation pulse to suppress edema and achieve a good contrast between lesion core and normal myocardium (Fig. 1c). Figure 2 compares visualization of acute RF lesions by non-contrast T1w and T2w techniques. The lesions are visualized as discrete hyper-intense regions in T1w image (Fig. 2b). Whereas, the individual lesions cannot be discriminated in T2w image (Fig. 2a). Non-contrast T1w MRI correlates well with conventional LGE-MRI and post-contrast T1w (Fig. 3).

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

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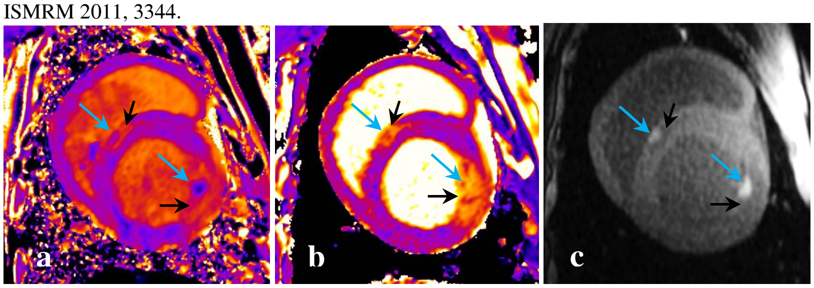

Figure 1. (**a**) T1 map, (**b**) T2 map, and (**c**) non-contrast T1w image of acute cardiac lesions. Blue arrow – lesion core, black arrow – edema.

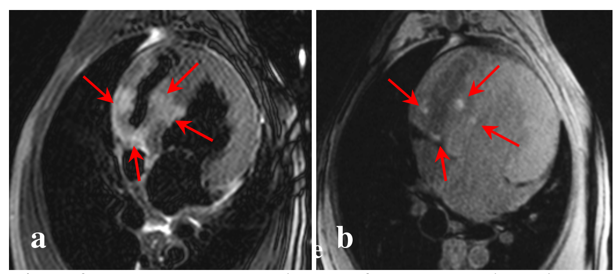

Figure 2. (**a**) T2w and (**b**) T1w images of acute RF cardiac lesions.

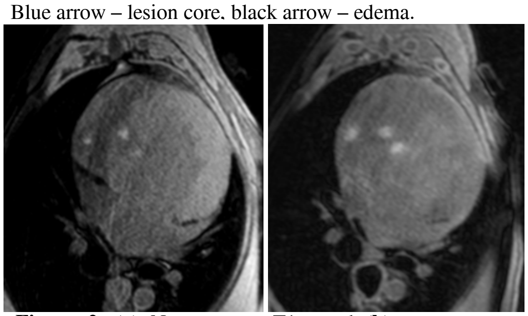

Figure 2. (**a**) Non-contrast T1w and (**b**) post-contrast T1w images of acute RF cardiac lesions.