

Visualization of Acute Atrial Injury by 3 Tesla MRI

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Introduction: Atrial fibrillation (AF) is the most common cardiac rhythm disturbance affecting more than 2 million people in the United States. Pulmonary vein isolation (PVI) procedure using radio-frequency (RF) ablation is effective in symptomatic, drug refractory AF. Still, reported success rates of the procedure vary significantly with AF recurrences ranging from 25-60%. The extent of LA wall injury at the time of ablation is difficult to assess with electro-anatomical mapping (EAM). With introduction of electro-physiology (EP)-MRI suites, patients may be re-ablated immediately after assessment of the extent of left atrial (LA) wall injury by MRI, if necessary. Late gadolinium enhancement (LGE) [1,2] and double inversion recovery (DIR) prepared T2-weighted (T2w) fast/turbo spin echo (FSE/TSE) [3-5] were proposed to evaluate acute LA wall injury. All earlier reports were from 1.5T studies and with only few patients imaged immediately after ablation procedure. In this study, we present our imaging protocol for immediately post-ablation assessment of LA wall injury by 3T MRI and report typical appearance of acute LA wall injury based on 50 patients study.

Theory and Methods: From June 2009 to November 2009, fifty patients underwent PVI and debulking of the septal and posterior walls under EAM guidance (CARTO, Biosense Webster) in EP-MRI suit. After the conclusion of ablation procedure, each patient was moved to 3 Tesla MR scanner (Verio, Siemens Healthcare). Time interval between the conclusion of ablation procedure and patient in the scanner was less than an hour. Imaging protocol has been developed and optimized for imaging at 3T to rule out procedure complications and assess the extent of injury to left atrial wall. The protocol includes contrast enhanced MR angiography (CE-MRA), DIR-prepared T2w HASTE and TSE, and 3D LGE scans. All sequences were respiratory navigated, ECG gated with data acquisition during LA diastole.

Conventional CE-MRA sequence with a fast rate of contrast injection (2.0-4.0 mmol/sec) and continuous data acquisition during one breath-hold (10-15 sec.) cannot be used for immediately post-ablation patients because the patients are typically sedated. Novel CE-MRA sequence with a slow rate of contrast injection (0.1 mmol/sec), respiratory navigation, and ECG gating has been developed. CE-MRA parameters were: TR/TE=1.3/2.8 ms, flip angle of 18°, bandwidth=750 Hz/pixel, FOV=400x400x110 mm, matrix size=320x320x44, 27% over-sampling in slice encoding direction, voxel size=1.25x1.25x2.5 mm, phase encoding direction: left to right, fractional readout=82.5%, partial Fourier acquisition: 80% in phase-encoding direction and 80% in slice-encoding direction, GRAPPA with R=2 in phase encoding direction. 73 k-space views were acquired during LA diastole. Typical acquisition time for CE-MRA study was 2.5 minutes.

Both 2D DIR-HASTE and 2D DIR-TSE were used to visualize post-ablation edema. DIR-HASTE parameters were: TE=73ms, TR=one respiratory cycle, fat suppression using spectral adiabatic inversion recovery (SPAIR), in-plane resolution of 1.25x1.98 mm, slice thickness of 4 mm, 24 slices, GRAPPA with R=2 and 34 reference lines. Typical acquisition time was 2 minutes. DIR-TSE parameters were: TE=83ms, TR=2RR, ETL=21, fat suppression using SPAIR, in-plane resolution of 1.25x1.25 mm, slice thickness of 4 mm, 20 slices, GRAPPA with R=2 and 42 reference lines. Typical scan time was 6 minutes.

High resolution LGE images of LA were acquired about 15 minutes after contrast agent injection (0.1 mmol/kg, Multihance (Bracco Diagnostic Inc., Princeton, NJ)) using a 3D respiratory navigated, inversion recovery prepared GRE pulse sequence with TR/TE=1.4/3.1 ms, flip angle of 13°, bandwidth=710 Hz/pixel, FOV=400x400x110 mm, matrix size=320x320x44, 9% 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: 80% in phase-encoding direction and 90% in slice-encoding direction, GRAPPA with R=2 in phase 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 LA diastole. To preserve magnetization preparation in image volume, navigator was acquired immediately after data acquisition block. Typical scan time for LGE study was 4-8 minutes depending on patient heart rate and respiration pattern.

Results: Typical CE-MRA, DIR-TSE, DIR-HASTE, and LGE images acquired during immediately post-ablation study are shown in Fig. 1. Novel CE-MRA technique improves visualization of LA and pulmonary veins in the comparison with conventional, non-ECG gated approach. Both DIR sequences visualize post-ablation edema clearly. However, typical scan time for HASTE sequences was about 2 minutes whereas scan time for DIR-TSE exceeded 6 minutes. Image quality for DIR-TSE was strongly dependent on regularity of heart rate while HASTE sequence gave good images regardless.

Discussion and Conclusion: The protocol for immediately post-ablation imaging of the AF patients at 3T has been developed. The main observations are the following: 1. Significant edema was detected not only in the regions subjected to RF energy (pulmonary veins ostia, posterior wall, septum) but also in distant regions (anterior wall) (Fig.1b and 1c). 2. LGE images demonstrate heterogeneous appearance of LA wall in the regions subjected to RF energy. Significant areas of these regions has minimal enhancement (Fig.2a, 2c, and 2e). Possible explanation of this phenomenon is a complete disruption of blood circulation in these regions similar to no-flow regions observed in left ventricle during acute stage of infarct.

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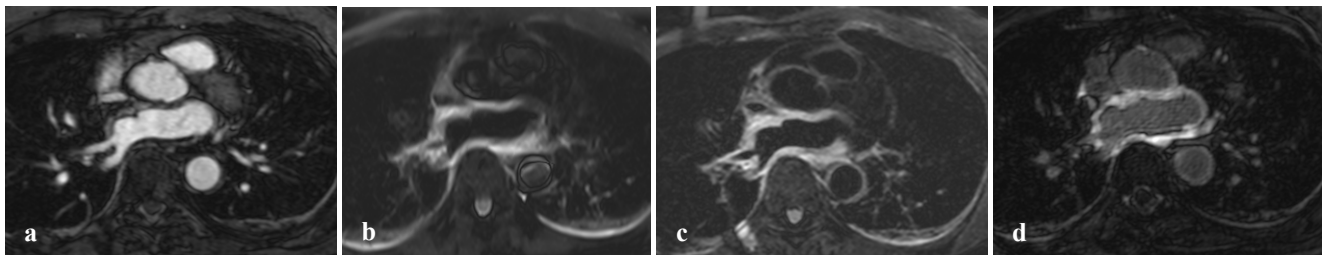


Figure 1. Immediately post-ablation images of left atrium: (a) CE-MRA, (b) DIR-HASTE, (c) DIR-TSE, (d) LGE

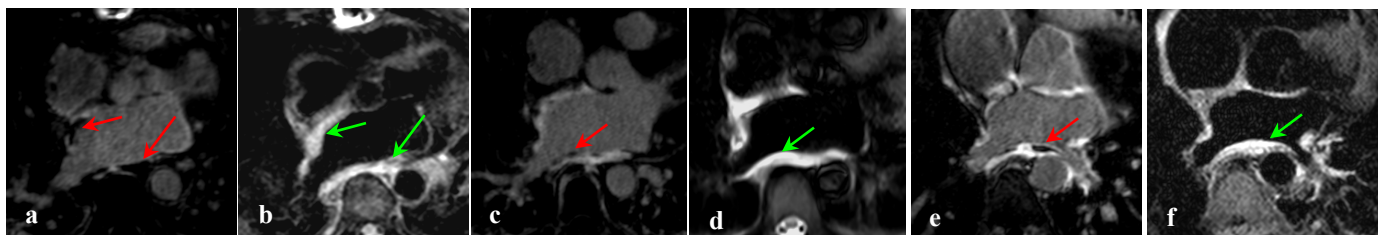


Figure 2. Illustration of spatial correlation between no-flow regions (red arrow) in LGE images (a,c,e) and edema regions (green arrows) in DIR-TSE (b, f) and DIR-HASTE (d).