Contrast Optimization for LGE imaging of Left Atrium

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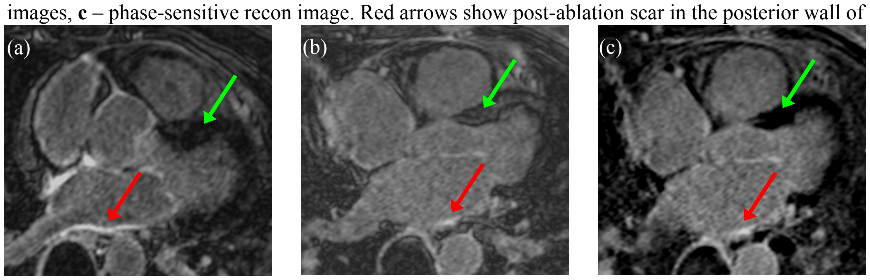
Introduction: Late gadolinium enhancement (LGE) using magnetic resonance imaging (MRI) is a widely used technique to detect infarcted regions in left ventricle. Recently, it was shown that high-resolution 3D LGE imaging can detect pre-ablation re-modeling of the left atrial wall [1] in patients with atrial fibrillation (AF) and also visualize post-ablation scar [2,3] in the AF patients treated using RF ablation. The choice of inversion time (TI) for LGE imaging of left atrium (LA) plays a crucial role in achieving high contrast between scar and myocardium and between scar and blood. Typically, TI is chosen using a TI-scout sequence such that normal myocardium is nulled. Such a choice usually gives good contrast between scar and myocardium but can result in sub-optimal contrast between scar and blood, especially when time interval between contrast agent injection and LGE imaging is short (10-15 minutes). In this work, dependence of contrast-to-noise ratio (CNR) between LA scar and blood (CNR_{SB}) and between LA scar and myocardium (CNR_{SM}) on TI values was studied using computer simulations and patient data. The analysis was performed for magnitude and phase-sensitive (PS) reconstructed LGE images [4,5] to identify optimal TI values for both reconstruction methods.

Theory and Methods: Realistic T1 values for post-ablation scar, myocardium, and blood were estimated by analyzing TI-scout images from 25 different patient studies and were found to be 120, 420 and 310 ms respectively. Simulations were performed with these values for an inversion recovery prepared gradient recall echo sequence (IR-GRE), with an RR interval of 1000 ms, TR of 5.1ms, TE=2.3ms, 25 readouts per RR, and flip angle 19º, using MATLAB (The Mathworks Inc. Natick, MA). Imaging studies were performed on a 1.5T Avanto MR system (Siemens Healthcare, Erlangen, Germany). 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, IR-GRE pulse sequence with TE/TR=2.3/5.1 ms, flip angle of 19º, bandwidth=240 Hz/pixel, FOV=360x360x100 mm, matrix size=288x288x44, 9% oversampling in slice encoding direction, voxel size=1.25x1.25x2.5 mm, phase encoding direction: left to right, fractional readout=83.3%, partial Fourier acquisition: 82.5% in phase-encoding direction and 87.5% in slice-encoding direction, GRAPPA with R=2 and 50 reference lines. Inversion pulse was applied every heart beat and fat saturation was applied immediately before data acquisition (25 views per heart beat) during LA diastole. To preserve magnetization preparation in the whole image volume, navigator was acquired immediately after data acquisition block. Typical scan time for LGE-MRI study was 5-10 minutes depending on patient heart rate and respiration pattern. Measurements of normal myocardium, blood pool and scar region were made in the LGE images (mean and standard deviation (std)) using Osirix software in 10 patients (3 or more months post ablation) for two cases. (a) When images were acquired with TI set to a value such that the myocardium was zeroed out and (b) when images were acquired with a TI when myocardium was negative (blood and myocardium had similar intensity) and magnitude and phase sensitive reconstructions were performed. Figure 1 shows typical LGE images for these two cases. CNR_{SB} and CNR_{SM} were estimated from computer simulated and patient data assuming that std of noise is 1 for the computer simulations and std of noise is equal to std of blood pool region for patient data measurements.

Results: Results of the computer simulations are presented in Fig.2. Figure 2a shows the dependence of magnetization of scar, myocardium, and blood on TI values of the LGE scan. The corresponding CNR_{SB} and CNR_{SM} curves are shown in Fig. 2b. The mean CNR_{SB} and CNR_{SM} computed from patient data are given in Table 1. From Table 1, it is seen that the CNR between scar and blood is almost the same for magnitude and PS reconstruction images, when TI was set to have a negative value of myocardium, while the CNR between scar and myocardium in PS reconstructed images is almost double that of magnitude images. The CNR between scar and blood improved by about 12.5% in the PS reconstruction when TI was such that the myocardium was negative, than when the TI was such that the myocardium was nulled. From Fig. 2 (a) and (b), similar observations were made. From Fig. 2(b), there is about 20% improvement in CNR_{SB} for the PS reconstruction case when myocardium and blood have similar magnitude but opposite phase in comparison with CNR_{SB} for TI to null myocardium.

Figure 1. LGE-MRI of left atrium with (**a**) TI chosen to null myocardium, (**b, c**) TI chosen to get similar intensity for myocardium and blood. **a** & **b** – magnitude recon images, **c** – phase-sensitive recon image. Red arrows show post-ablation scar in the posterior wall of LA. Green arrows show normal myocardium.



Conclusion: The presented results of the computer simulations and patient data indicate that to achieve the best CNR between scar and myocardium and scar and blood, the TI value for LGE images of the LA should be set such that the myocardium and blood have similar magnitude but opposite phase and phase sensitive reconstruction should be performed. It can also be noted that CNR_{SB} and CNR_{SM} are less sensitive to TI value prescribed, when phase sensitive reconstruction is used.

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References: [1] Oakes RS et al. Circ 2009;119:1758-67. [2] Peters D, et al. Radiology 2007;243:690-5. [3] McGann CJ, et al. JACC 2008;52:1263-71. [4] Kellman P, et al. MRM 2002;47:372-83. [5] Kholmovski EG, et al. ISMRM 2009.

Table 1. CNR_{SM} and CNR_{SB} of magnitude and phase reconstruction for different values of TI

CNR_{SM}			CNR_{SB}		
Magnitude recon	Phase recon	Magnitude recon – myocardium nulled	Magnitude recon	Phase recon	Magnitude recon – myocardium nulled
7.08	12.56	13.2	5.09	5.2	4.6

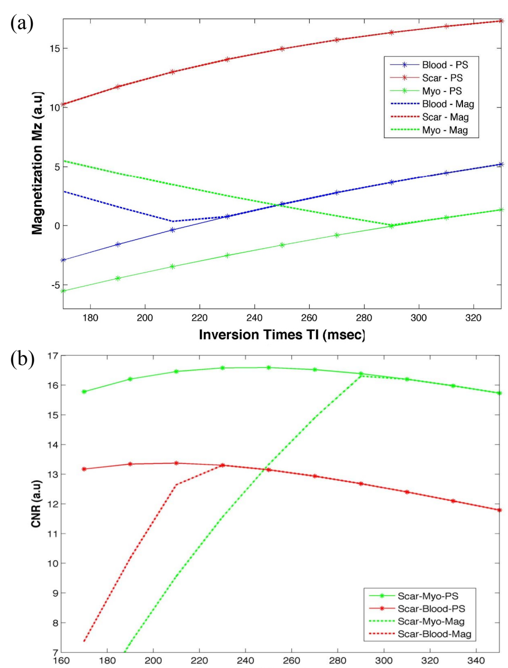

Figure 2. (a) Magnetization recovery curves for different TIs. (b) CNR vs. TI for magnitude and phase-sensitive reconstruction.