Calculation of Optimal TI Value for 3D LGE-MRI of the Left Atrium

Eugene G. Kholmovski[1,2], Sathya Vijayakumar[1,2], and Nassir 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*

Purpose: High resolution, 3D late gadolinium enhancement (LGE) MRI can be used to evaluate structural changes in the left atrium (LA) wall (e.g. fibrosis) caused by atrial fibrillation (AF) and to detect scarring of the LA wall caused by interventional procedures to treat AF (e.g. radiofrequency (RF) ablation, cryo-ablation, etc.).[1-3] It was shown that success of RF ablation procedure is strongly correlated with degree of pre-ablation LA remodeling detected by LGE-MRI.[3,4] Scar map of LA is helpful in planning and performing repeat ablation procedures.[5] Accuracy of fibrosis/scar evaluation is strongly dependent on quality of LGE-MRI of LA. The choice of inversion time (TI) for LGE-MRI of the left atrium plays a crucial role in achieving high contrast between scar and normal myocardium and between scar and blood. Usually, TI value for cardiac LGE-MRI is found using TI-scout scan based on Look-Locker technique.[6] This scan is performed applying inversion RF pulse every second or third heart-beat. The images from TI-scout are visually analyzed to select the image with minimal intensity of myocardium of the left ventricle. Value of TI corresponding to this image is considered to be optimal for subsequent cardiac LGE-MRI scans. However, this approach is not applicable in the case of LGE-MRI of LA because this pulse sequence applies inversion pulse every heart beat to keep scan time acceptable for patients (< 10 minutes). Images from TI scout with inversion pulse applied every heat beat is difficult to analyze due to poor CNR. Furthermore, TI value found from such TI-scout scan was found to be sub-optimal for LGE-MRI of the left atrium. The main goal of this work was to develop practical method to calculate optimal TI value for LGE-MRI of LA.

Methods: We have developed the following method for calculation of TI parameter for high resolution 3D LGE-MRI of the left atrium:

1. Run conventional TI-scout scan with inversion RF pulse applied every second or third heart-beat. It is preferable to use inversion pulse every third-heart beat for patients with fast heart rates (> 90 beats per minutes (bpm)) to improve CNR of the scout images.
2. Find TI value (TI_{scout}) corresponding to minimal intensity of normal myocardium of the left ventricle by visually inspecting a set of the images from the TI-scout scan.
3. Calculate T1 value for the normal myocardium using TI_{scout} and time interval between inversion pulses (T_{IR}) in TI-scout scan. The calculation is performed using an iterative algorithm:

$$T1_{n+1} = TI_{scout}\frac{1}{\ln(2)-\ln(1+e^{-T_{IR}/T1_n})}$$

where N is the prescribed number of iterations, T_{IR} is a time interval between inversion pulses in TI-scout scan. T_{IR} is equal to two or three the mean intervals between adjacent R-waves (2RR or 3RR) depending on TI-scout protocol. Initialization for the iterative algorithm: for n=0, $T1_n$=0. This algorithm has a fast convergence. N=5 is enough to achieve accuracy higher than 1%.

4. Calculate optimal TI for LGE-MRI of the left atrium:

$$TI_{LGE} = T1\cdot\ln\left(\frac{2}{1+e^{-T_{IR}/T1}}\right)$$

where $T1$ is T1 value found in Step 3, T_{IR} is a time interval between inversion pulses in LGE-MRI scan of the left atrium. T_{IR} is equal to the mean time interval between adjacent R-waves (1RR).

Retrospective analysis of LGE-MRI scans of the left atrium acquired at a 3 Tesla Verio scanner (Siemens Healthcare, Erlangen, Germany) was performed. 20 scans were acquired with TI value found from TI-scout (TI_{scout}). The other 20 scans were acquired using TI value estimated using the proposed method (TI_{LGE}). High resolution 3D 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 14^o, bandwidth=750 Hz/pixel, FOV=400x400x110 mm, matrix size=320x320x44, voxel size=1.25x1.25x2.5 mm, 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. Typical scan time for LGE study was 4-8 minutes depending on patient respiration pattern.

Results: Typical LGE-MRI images of the left atrium acquired using TI_{scout} and TI_{LGE} values for inversion time are shown in Figure 1. TI_{scout} has sub-optimal value for LGE-MRI resulting in poor image quality. The image acquired with TI_{LGE} has a good contrast between post-ablation scar and blood and normal myocardium. Figure 2 illustrates dependence of difference between TI_{scout} and TI_{LGE} on patient heart rate. It is obvious that TI-scout gives acceptable TI value for patients with low heart rate and small TI_{scout} values (high contrast dose or shortly after contrast injection). However, for practical contrast doses and typical heart rates, TI-scout seriously overestimates TI value to be used in LGE-MRI of the left atrium. From 20 LGE-MRI of LA scans performed using TI_{scout} value, only 7 have good or acceptable quality, whereas, only 1 LGE-MRI of LA with TI_{LGE} value has poor quality.

Conclusion: A novel method for calculation of optimal TI value for LGE-MRI of the left atrium has been developed and validated. The results of the patient studies shown a great improvements in quality of LGE images of LA when this method was used to calculate inversion time of the scan.

Acknowledgments: This study was supported in part Ben B. and Iris M. Margolis Foundation.

References: 1. Oakes RS et al. Circulation 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. Akoum NW et al. JCE 2011;22;16-22. 5. Badger TJ, et al. Circulation: Arrhythm and Electrophysiol 2010;3:249-59. 6. Look DC, Locker DR. Rev Sci Instrum 1970;41:250-1

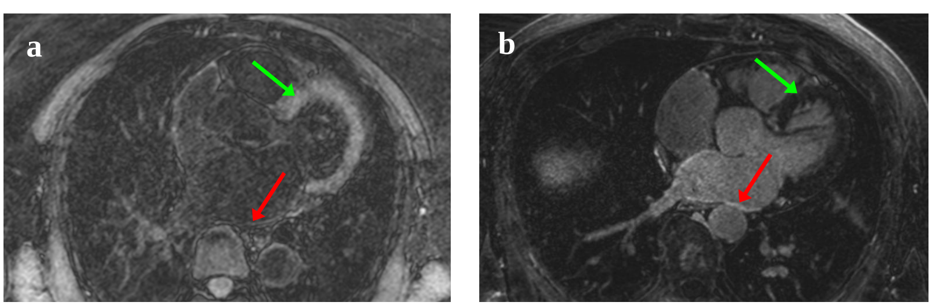

Figure 1. LGE-MRI of left atrium with (**a**) TI chosen from TI-scout, (**b**) TI calculated using the proposed method. Red arrows show post-ablation scar in the posterior wall of LA. Green arrows show normal myocardium.

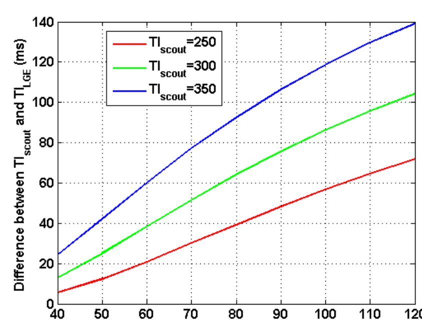

Figure 2. Difference between TI_{scout} and TI_{LGE} for different heart rates and TI_{scout} values.