Analysis and Optimization of the IR-GRE delayed enhancement MRI sequence used for imaging post RF ablation scars in the posterior wall of the left atrium

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Introduction: Radio frequency (RF) ablation of the left atrium (LA) and pulmonary vein (PV) ostia has become a clinically acceptable therapy for atrial fibrillations (AF) [1,2]. Recently, a delayed enhancement MRI (DE-MRI) technique has been proposed to visualize and assess the extent of post RF ablation scar in the LA [3]. This method uses an inversion recovery 3D gradient echo (IR-GRE) sequence with an interval of 1 RR between inversions. This sequence typically employs fat saturation during the acquisition to distinguish between fat and ablation scar. Good contrast between scar - myocardium, scar - blood and scar - fat are very important to quantify the extent of post ablation scar reliably. This study aims to understand and improve the performance of this DE-MRI sequence by identifying optimum values of flip angle (FA) and inversion time (TI), to get better image contrast.

Methods: The IR-GRE sequence was simulated using MATLAB (The Mathworks Inc. Natick, MA) with TR = 1RR (approximated to 800 msec for average people), TI ranging from 180 to 240 msec, FA ranging from 10 to 35 degrees, and with acquisitions of n = 21 lines per heart beat, with a spacing of TR2 = 6.5 msec between the α pulses. To estimate the T1 value of the tissues under consideration, T1 scout images of 10 patients acquired approximately 15 minutes after contrast administration were analyzed. All patient data were acquired using a 1.5T Siemens Avanto scanner (Siemens Medical Solutions, Erlangen, Germany). The calculated T1 values for blood, myocardium, fat and scar tissue were 240, 380, 255 and 150 msec respectively. The plots in Figure 1 show the normalized longitudinal magnetization recovery curves obtained for the T1 values corresponding to blood, myocardium, fat (with and without the use of fat saturation) and scar tissue for a TI of 200 msec and FA = 17. All computer simulations were performed assuming the order of k-space acquisition to be center-out (center of k-space acquired first, higher frequency acquired later). The contrast between scar - blood, scar - myocardium and scar - fat were computed according to this expression: $C = |scar| - |x|$, where x = blood, myocardium and fat

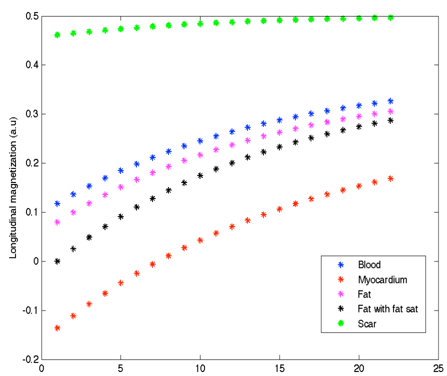

Fig. 1 Longitudinal magnetization recovery during acquisition of 21 k-space lines per heart beat

Results: Figure 2 shows the 3-D plot of contrast computed for the center of k-space (assuming center-out ordering in k-space) for different values of FA and TI. Although the center of k-space plots indicates that higher FA and higher TI would improve contrast, the scars we want to visualize are very thin (typical example shown in Figure 3), thus making the high frequency component important as well. Figures 4 (a), (b) and (c) show the same contrast plots for the high frequency components in k-space, while figures 5 (a), (b) and (c) show the same contrast plots averaged over entire k-space. Figure 6 illustrates that fat saturation is never optimal (as seen from the recovery curves in Fig. 1, by the time higher frequency data are acquired, fat recovers too). Here, the phase information plays an important role in distinguishing scar from fat. The green arrow indicates a region where the phase image can clearly distinguish fat from scar, the red arrow shows scar.

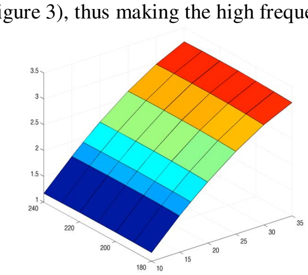

Fig. 2(a) Contrast between Scar & Blood (Low freq)

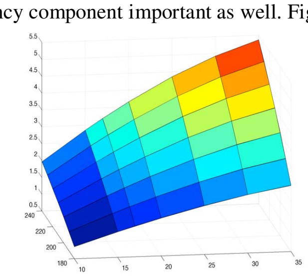

Fig. 2(b) Contrast between Scar & Myocardium (Low freq)

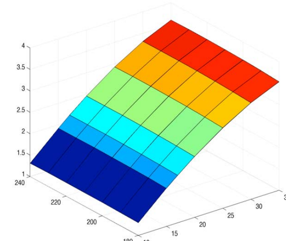

Fig. 2(c) Contrast between Scar & Fat (Low freq)

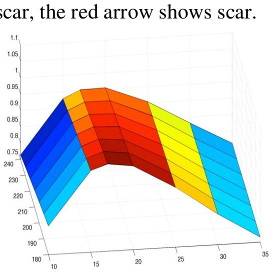

Fig. 4(a) Contrast between Scar & Blood (High freq)

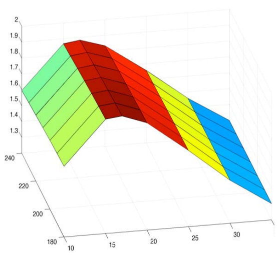

Fig. 4(b) Contrast between Scar & Myocardium (High freq)

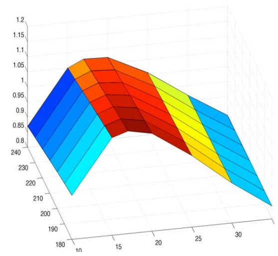

Fig. 4(c) Contrast between Scar & Fat (High freq)

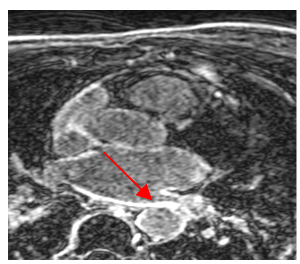

Fig 3. Example of a typical post –ablation DE-MRI scan

Fig. 6(a) Magnitude image of DE-MRI scan

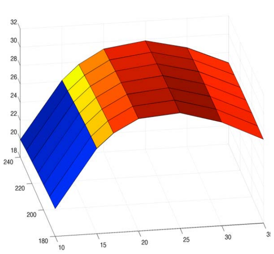

Fig. 5(a) Contrast between Scar & Blood (Avg)

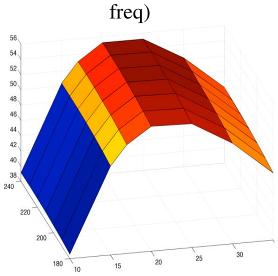

Fig. 5(b) Contrast between Scar & Myocardium (Avg)

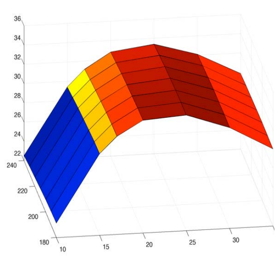

Fig. 5(c) Contrast between Scar & Fat (Avg)

References: 1. Haissaguerre M et al. *N Engl J Med* 1998; 339:659-666. 2. Cappato R et al. *Circulation* 2005; 111:1000-1105. 3. Peters D. et al. *Radiology* 2007;243:690-695.

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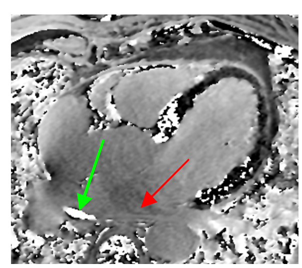

Fig. 6(b) Phase image of DE-MRI scan

Conclusion/Discussion: From our analysis and the supporting patient images, we conclude that the DE-MRI sequence for LA scar imaging would perform optimally if the flip angle is chosen in the range 20-25 degree. The phase images are very valuable to differentiate between scar and fat. Future work will determine how the ordering in k-space will affect the sequence performance as well.