hp-GRAPPA for Delayed Enhanced Imaging of the Left Atrium

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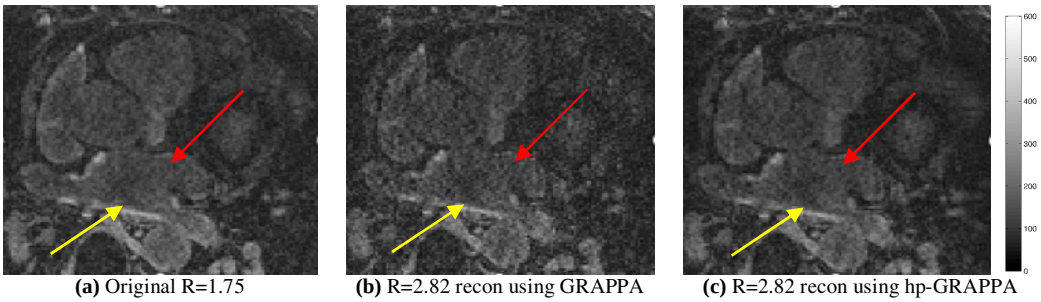
Introduction: Radio frequency (RF) ablation of the left atrium (LA) and pulmonary vein (PV) ostia has become a clinically acceptable therapy for atrial fibrillation (AF) [1,2]. Recently, a delayed enhancement MRI (DE-MRI) technique has been proposed to visualize and assess the extent of post-ablation scar [3]. This technique visualizes scar in the posterior wall of the LA and the PV ostia where the RF ablation has been performed. This can be useful for predicting outcome of procedure [4] and to detect gaps in the ablation pattern for repeated ablation procedures. To quantify scar and predict procedure outcome, one needs to be able to visualize wall of the LA very accurately. It should be noted however, that the wall of the LA is very thin (2-5 mm) and hence, the high frequency components of k-space are critical for the best reconstruction of these images. Recently, in [5], a reconstruction scheme was proposed for parallel imaging where high frequency components of k-space are better preserved and reconstructed with the use of a high pass filter. In this work, we applied this technique, high-pass GRAPPA (hp-GRAPPA), to get better DE image quality at higher acceleration factors.

Methods: The DE images of LA were acquired using a 3D respiratory navigated, inversion recovery prepared gradient echo pulse sequence with phase encode direction left to right, acceleration factor 2, ACS lines: 46, 10% oversampling in slice direction, TR/TE: 2.3/6.1 msec, flip angle: 22, matrix size: 320x322x40, voxel-size: 1.25x1.25x2.5mm. This originally acquired dataset with R=1.75 (R=1 for central 46 lines and R=2 for outer k-space regions), was further undersampled to R=2.82 (R=4 for outer k-space regions), keeping the same 46 ACS lines. The high pass filter was designed as per the description in [5], taking into account the reduction factor, number of ACS lines and the number of coils. The 'c' and 'w' values chosen were: 16 and 2. The conventional GRAPPA and hp-GRAPPA reconstructions were both implemented using a 4x5 kernel size.

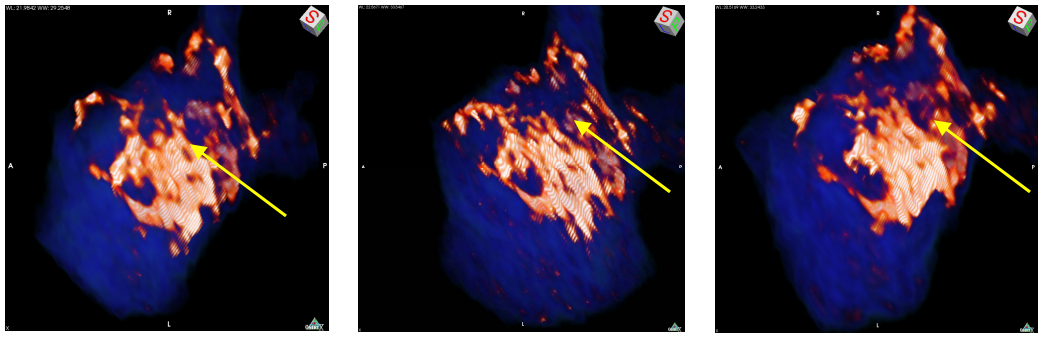
This undersampled dataset with R=2.82, was reconstructed using conventional GRAPPA and hp-GRAPPA. The images were then processed by evaluating the images slice-by-slice and using volume rendering tools. The epicardial and endocardial boundaries were manually contoured. Normal and injured (enhanced) tissue were defined based on a bimodal distribution of pixel intensities within the LA wall. The first mode of lower pixel intensities was chosen to be normal and the injured tissue was defined at 3 standard deviations above the normal tissue intensity. The LA scar area was summed for the entire scan and expressed as the ratio of the scar volume to total LA wall volume. All reconstructions and processing were performed using custom software written in MATLAB (The Mathworks Inc., Natick, MA).

Results: Figure 1 illustrates the images reconstructed using GRAPPA for the original R=1.75 and those from the simulated R=2.82 dataset using the traditional GRAPPA technique and hp-GRAPPA technique. To evaluate image quality, the difference map was defined to be the difference image between the R=2.82 and the R=1.75 reconstructed images. The mean and standard deviation (mean ± SD) of the difference image from the 2 techniques are also given in Figure 1. The red arrow points to the LA volume in the image and the yellow arrow shows ablation scar in the posterior wall of the LA. Figure 2 illustrates the 3D volume rendered images of the original R=1.75 data and the R=2.82 data reconstructed using GRAPPA and hp-GRAPPA techniques. The estimated percentage scar in the LA is also given in Figure 2.



(a) Original R=1.75 **(b)** R=2.82 recon using GRAPPA Noise: 16.3 ± 1.78 **(c)** R=2.82 recon using hp-GRAPPA Noise: 12.67 ± 1.57

Figure 1. Images reconstructed using the GRAPPA and hp-GRAPPA for undersampled data with R=4.



(a) Original R = 1.75 Percentage Scar: 26.75% **(b)** R=2.82 recon using GRAPPA Percentage Scar: 22.39% **(c)** R=2.82 recon using hp-GRAPPA Percentage Scar: 26.72%

Figure 2. 3D volume rendered images of the LA (yellow arrow indicates the posterior wall).

Conclusion/Discussion: From the figures, the noise levels and the estimated percentage scar values, it can be observed that the reconstruction employed using hp-GRAPPA gives images that are close to the originally acquired clinical data. This work shows promising results that with the implementation of hp-GRAPPA for DE imaging of the LA, faster imaging (up to twice) can be achieved without significant loss of image quality and post processing results comparable to the original R=1.75 clinical acquisition.

Acknowledgments: This study was supported in part by Ben B. and Iris M. Margolis Foundation, SurgiVision Inc and Siemens Healthcare.

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