Optimal Sequence Weighting for 3D Dynamic Contrast Enhanced Imaging

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Introduction: Three dimensional (3D) evaluation of complex plaque and comprehensive coverage of vessel segments in clinical studies and preclinical models is important for the assessment of vascular disease [1-2]. The presence of permeable microvasculature is a hallmark of vulnerable plaque that can be assessed with Dynamic Contrast Enhanced (DCE) imaging [3-4]. However, use of 3D sequences is challenging for DCE as they require lengthy acquisition time to obtain the desired coverage. Choosing the optimal acquisition strategy to maximize CNR is important to facilitate acceleration of these acquisitions for improved temporal resolution. Here, we compare several gradient-echo (GE) and spin-echo (SE) based acquisitions for their image quality and T1-weighting and apply them in an atherosclerotic rabbit model.

Methods: Three GE sequences were based on segmented turbo field echo acquisition, similar to MERGE [1] and employed different TR and flip angle (FA). The SE sequence was a variable flip angle turbo spin echo acquisition, based on SPACE [2]. In each case $^{6}/_{8}$ partial Fourier (pF) acquisition or 2-fold under-sampling with GRAPPA reconstruction (G2) was assessed in order to achieve a temporal resolution close to 30 seconds per frame. Fat saturation was used on all sequences. For GE, flow crushing was achieved in the non-flow-compensated read gradient, which was oriented along the aorta. All sequences had isotropic 0.63-mm resolution over FOV 160x96x12.6 mm. Parameters are shown in the Table. On a 3T Siemens mMR system with a 6-ch body array, images were acquired in a phantom with varying concentrations of gadolinium contrast agent (Magnevist) in a range typically expected in the vessel wall. The vials at T1 of 1000, 650, 400, and 220 ms correspond to concentration in the vessel wall of 0, 0.13, 0.4, and 0.9 mM. SNR values were found from ROI measurements. The noise value was estimated from the standard deviation of signal in one vial (T1=400ms) to avoid bias of magnitude image reconstruction at low SNR. CNR was calculated between two of the vials representative of a pre-contrast and post-contrast T1 in the vessel wall (1000 ms and 400 ms) in a typical DCE experiment. Finally, a subset of sequences were used to acquire DCE in an atherosclerotic rabbit model [4] to assess in vivo image quality.

Sequence	Kernel	TR / ms	TE / ms	FA / deg	BW / Hz/pix	Turbo factor	Shot duration (acquisition) / ms	Trajectory	Scan time* / s
MERGE 6	SPGR	12.1	5.7	6	130	90	1111 (1089)	Centric	36/24
MERGE 25	SPGR	12.1	5.7	25	130	90	1111 (1089)	Centric	36/24
GRE 20	SPGR	7.1	3.25	20	362	38	600 (270)	Centric	38/26
SPACE	SE	500	25	90+	454	55	500 (273)	Linear	43/38, 29**

* Times shown are for partial Fourier / 2-fold under-sampling with GRAPPA reconstruction
**Combined partial Fourier and GRAPPA reconstruction
\+ Siemens T1-weighted variable flip angle train

Results: CNR results (Fig. 1) indicated that MERGE 6 showed poor contrast between pre- and post-contrast conditions. In all cases, partial-Fourier was preferred to GRAPPA reconstruction, except for SPACE where both accelerations were required to achieve temporal resolution close to 30 sec. Pre-contrast imaging (Fig. 2, top) showed that GRE exhibited blurry images, which we attribute to the k-space modulation resulting from non-steady state conditions associated with the recovery period. Post contrast images (Fig. 2, bottom) showed MERGE 25 and SPACE to have good contrast with the pre-contrast image. SPACE was also blurry, particularly around the stomach probably due to motion during the echo train.

Conclusion: MERGE with FA 25° showed both high contrast before and after CA administration and good image sharpness that allowed depiction of vessel wall CA uptake in the atherosclerotic rabbit aorta. Improvements in 3D DCE of the vessel wall is expected from the proposed method.

References: 1: Balu N, MRM. 2011 Mar;65(3):627-37. 2: Fan Z, JMRI. 2010 Mar;31(3):645-54. 3: Virmani R, J Am Coll Cardiol, 2006; 47(8 Suppl):C13-8; 4. Calcagno C, Arterioscl Thromb Vasc Biol, 2008; 28(7):1311-7

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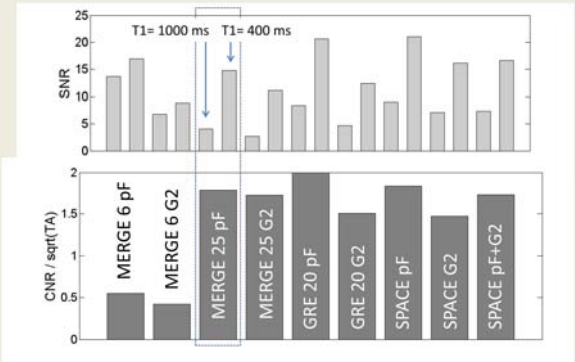

Figure 1: SNR (top) and CNR (bottom) from the T1 phantom for each sequence. CNR is normalized per square root unit scan time. For SNR above, each scan technique is shown for T1=1000ms and T1=400ms side by side. CNR is the difference of these values.

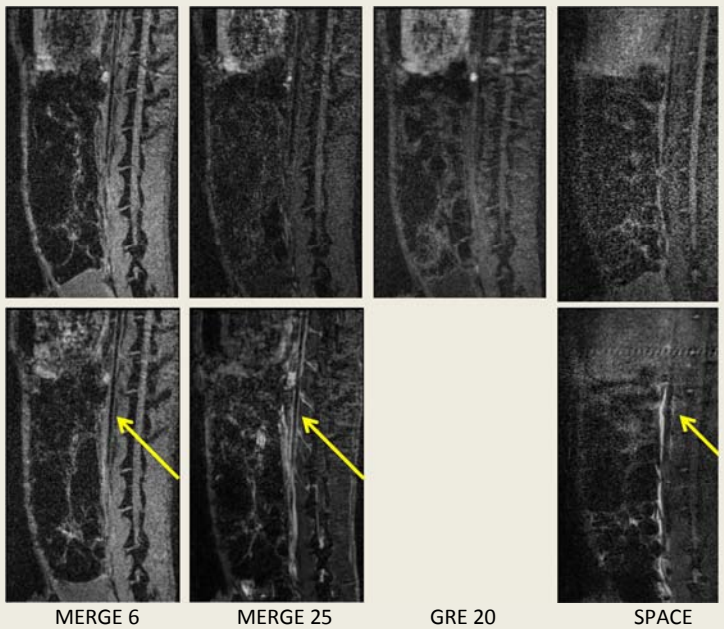

Figure 2: Pre- (top), and post-contrast images (bottom). Arrow shows vessel wall.