Pre-contrast and post-contrast isotropic 3D black-blood MRI with identical imaging parameters

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Introduction: Atherosclerotic plaque components such as lipid-rich necrotic core can be accurately identified by comparison of pre and post- gadolinium contrast black blood MRI. In order to facilitate such comparison specific blood suppression techniques such as quadruple inversion recovery (QIR) have been invented so that the same imaging parameters can be used for pre and post-contrast MRI despite shortening of blood T1 post-contrast [1]. However such techniques are limited to 2D MRI. 3D black blood imaging post-contrast imposes additional challenges due to larger imaging volume and longer scan times. Recent 3D black blood MRI techniques such as 3D MSDE prepared rapid gradient echo (3D-MERGE) can achieve large coverage pre-contrast MRI in short scan times [2]. However their extension to 3D post-contrast black blood MRI requires optimization of flow suppression using identical imaging parameters for both pre-contrast and post-contrast scans.

Aims: 1) To optimize imaging parameters of 3D-MERGE to achieve pre and post-contrast blood suppression with the same imaging parameters

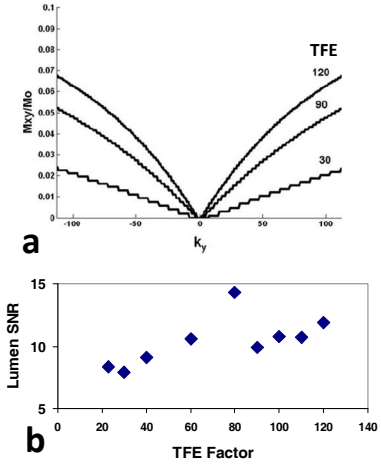

Figure 1: a) Bloch simulation showing that recovery of blood T1 at outer edges of k-space is less at lower TFE. b) Invivo measurement shows lower lumen SNR at lower TFE

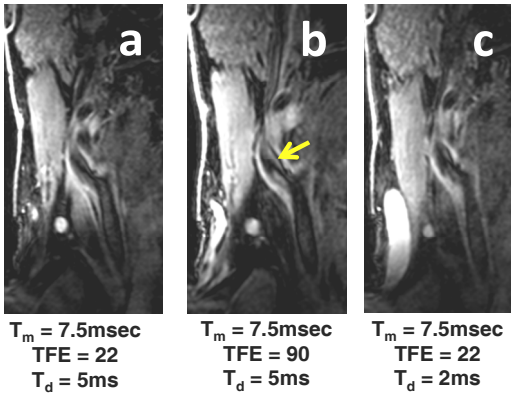

Figure 2: Invivo sagittal reformats show shorter TFE produces less flow artifacts at the same T_d (compare a and b). At the same TFE reducing T_d provides a further but minor improvement in flow suppression (compare a and c).

Materials and Methods: All MRI experiments were conducted using a Philips 3T Achieva and carotid phased array coils. 3D-MERGE was implemented with iMSDE preparation and spoiled segmented FLASH (T1-TFE) readout. Post MSDE delay T_d and Turbo factor (TFE) of the FLASH readout were optimized based on simulation and imaging in volunteers. The optimized sequence parameters were validated in patients with 15-79% stenosis. A T_m of 7.5ms with MSDE gradient amplitude 25 mT/m and slew rate 100 mT/(m.msec) were used. Isotropic voxels of 0.8x0.8x0.8 mm were acquired within 2.5 min scan time for each scan. Other sequence parameters were similar to previously published parameters [2] (TR: 10ms, TE: 4.8 ms, flip angle 6°, NSA: 1, Bandwidth 134.3 Hz/pixel). **Sequence optimization:** Immediately following the MSDE pulse, blood signal recovers and modulates k-space based on the TFE factor and profile order. Centric encoding ensures best flow suppression by acquiring center of k-space when blood signal is least recovered. Bloch equation simulation of the 3D-MERGE signal showed that flow suppression is improved with reduced TFE and to a lesser extent by reducing T_d. Lumen SNR was measured in a series of 3D-MERGE acquisitions with TFE factors ranging from 22-120. The effect of reducing TFE and T_d were confirmed in subjects with atherosclerosis. 3D-MERGE pre and post-contrast MRI with optimized parameters were compared to QIR in patients with 15-79% carotid stenosis by Doppler.

Results: Lower TFE factor and lower T_d was predicted by bloch simulation to improve flow suppression. Lumen SNR measurements invivo confirmed lower lumen SNR with lower TFE factors (figure 1). At identical TFE factors invivo flow suppression was slightly improved by lowering T_d (figure 2). Final optimized parameters for both pre and post-contrast 3D-MERGE were identified to be TFE 22 and T_d 0.5ms. The optimized parameters showed good blood suppression along the length of the artery (figure 3). Comparison with matched axial 2D QIR showed similar quality of pre and post-contrast flow suppression in axial reformats and good delineation of plaque components (figure 4).

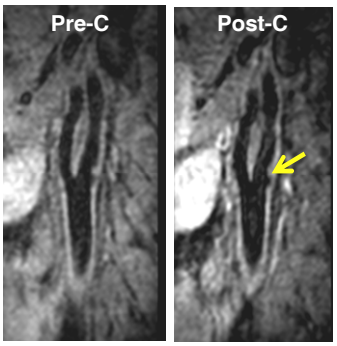

Figure 3: Sagittal reformat of pre and post-contrast 3D-MERGE showing flow suppression along the length of the artery. Arrow shows juxtaluminal calcification in plaque. Identical imaging parameters were used for both scans. Optimized TFE 22, T_d 0.5ms

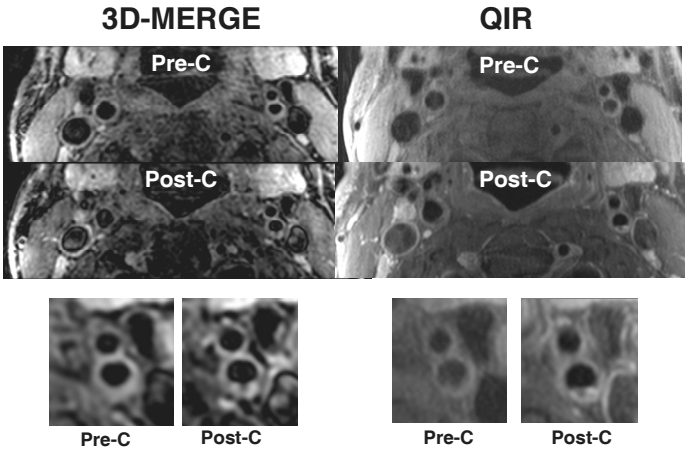

Figure 4: Comparison of 3D-MERGE axial reformats and 2D QIR pre and post-contrast black blood imaging. Lower panel shows good blood suppression and similar enhancement of plaque features on 3D-MERGE.

Discussion and Conclusions: Pre and post-contrast 3D black blood MRI can be achieved with identical scan parameters. A short TFE factor and short post MSDE delay are required for adequate flow suppression post-contrast.

References: [1] Yarnykh MRM 2002, [2] Balu, MRM, 2010