Complex Subtraction – A Flow-Independent Method For Vessel Wall Imaging Shortly After Gadofluorine Injection

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Introduction: Suppression of blood signal (i.e. black-blood imaging) is desired during MR imaging of atherosclerotic disease to clearly depict the arterial wall. Three magnetization preparations which provide for black-blood imaging include: double inversion-recovery (DIR) [1], regional saturation (SAT) [2], and diffusion (DIF) [3]. However, these magnetization preparations are flow-dependent, and may therefore fail to suppress blood signal under conditions of slow blood flow. Contrast-enhanced MR imaging has been utilized to enhance depiction of diseased arterial wall [4-7]. Unfortunately, suppression of blood signal during contrast-enhanced vessel wall imaging is difficult due to significantly shortened blood T_1.

Clearly, flow-independent methods to robustly eliminate short T_1 blood signal shortly after contrast administration are desired to accurately probe post-contrast enhancement of diseases affecting the arterial wall. Gadofluorine, a paramagnetic blood-pool MR contrast agent with higher T_1 relaxivity than Gd-DTPA, has been reported to enhance atherosclerotic arterial wall an hour after injection [3]. In this work, we investigated whether complex subtraction [8] – a technique which we hypothesize may allow for flow-independent suppression of contrast-enhanced blood – could be utilized for gadofluorine-enhanced vessel wall imaging.

Methods: All imaging experiments were performed in a 1.5 T whole-body clinical scanner (Sonata; Siemens Medical Systems, Erlangen, Germany). MR imaging of the carotid arterial wall of Yucatan miniswine was performed within 1 hour after intravenous injection of gadofluorine at a dose of 100 µmole/kg. Inversion-recovery (IR) prepared segmented FLASH imaging was performed at two different inversion times. In image (a), TI_A, a short inversion time allowed the longitudinal magnetization of the short-T1 gadofluorine-enhanced blood to relax substantially to its equilibrium magnetization while suppressing signals from longer-T1 tissues such as vessel wall, resulting in bright blood and dark wall. In image (b), TI_B, a longer inversion time allowed both blood and vessel wall to relax substantially to their equilibrium magnetizations, resulting in bright blood and bright wall. Complex subtraction of images (a) and (b) was performed to suppress signal from short-T_1 blood enhanced by gadofluorine while retaining vessel wall signal. Imaging was performed with the following imaging parameters: TR/TE = 6.8/3.0 ms, FOV = 20×20 cm^2, imaging matrix = 384×384, TI_A = 300 ms, TI_B = 800 ms, SL = 3 mm, segments per repetition = 25, repetition interval = 1 s, fat saturation, bandwidth = 200 Hz/pixel, flip angle = 20°, NEX = 10, imaging time = 160 s.

Results & Discussion: The proposed complex subtraction scheme was successfully performed within an hour after gadofluorine injection. Images of the carotid artery wall acquired with the proposed complex subtraction scheme are shown (Fig. 1). Carotid wall-lumen CNR for the images shown in Figure 1 was -22.3, -8.8, and +7.3 with TI_A, TI_B, and complex subtraction, respectively.

Conclusion: Complex subtraction is a promising flow-independent technique for blood suppressed vessel wall imaging shortly after injection of gadofluorine, and may be a promising technique for assessing plaque enhancement following injection of plaque-targeting, T1-shortening, blood-pool contrast agents. Further work is needed to validate the effectiveness of the technique in blood signal suppression and to determine optimal imaging parameters (e.g. inversion times, etc.) to better highlight the arterial wall.

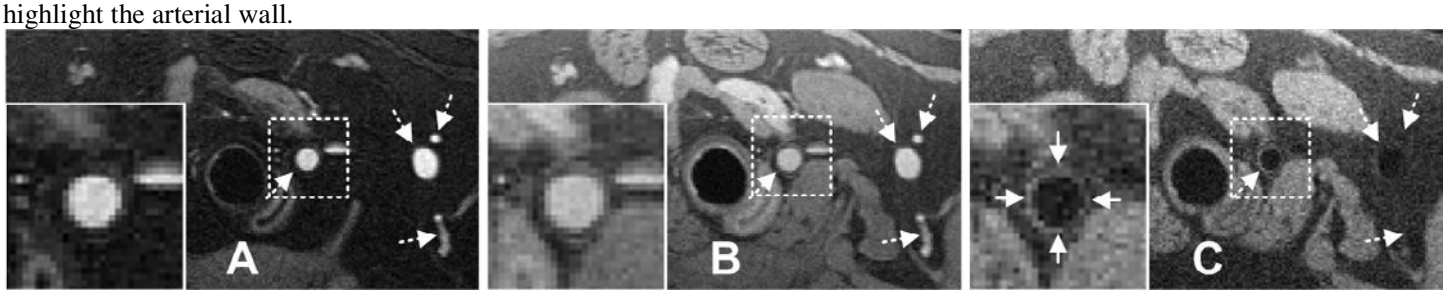

Figure 1. Images acquired with IR prepared segmented FLASH an hour after injection of gadofluorine at a dose of 100 µmole/kg. **A**, Image acquired at TI_A = 300 ms depicts bright signal from short T_1 blood (dashed arrows) due to near complete longitudinal relaxation towards the equilibrium magnetization, M_0. **B**, Image acquired at TI_B = 800 ms allows for greater longitudinal recovery of longer T_1 tissues, while blood remains bright in appearance (dashed arrows). **C**, Complex subtracted image (subtraction of image A from image B) robustly suppresses intravascular contrast-enhanced blood signal (dashed arrows), and facilitates visualization of the left common carotid arterial wall (solid arrows in inset).

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