Radial Off Resonance Contrast Angiography

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Introduction:

MR angiography using Off-Resonance Contrast-enhanced Angiography (ORCA) eliminates the need for mask-mode subtraction [1]. ORCA MRA relies on off resonance RF excitation pulses that allow for acquisitions which "tune in" enhanced arteries while "tuning out" signals from background. ORCA is predicated on well tailored RF pulses and required longer TRs (> 6 ms) that normally used in MRA. We have developed a novel approach to CE-MRA which is based on a previously reported MR fluoroscopy acquisition [2]. Our approach uses radially sampled k-space and temporal view-sharing based on a sliding window reconstruction. By sampling the center of k-space on each echo, we avoid large integration window and dynamic MRA scans with high temporal fidelity are possible. We report on a radial-sliding window [3] ORCA sequence for dynamic angiography with high resolution (0.8 mm x 0.8 mm), in both space and time (sub-second), without the need for mask-mode subtraction.

Materials and Methods:

The pulse sequence consists of a frequency selective excitation at a frequency shifted from the Larmor frequency, followed by radial 3D FLASH acquisition. Radial ORCA images were acquired with the following parameters: FOV = 220 mm/ N_p=128, N_{slices}=16, slice thickness=2.0 mm, TR/TE= 8.0 ms/ 2.77 ms, flip angle = 25°. The excitation RF pulse was a 4000 microsecond sinc pulse with a frequency bandwidth of about 833 Hz. Gradient and clock-shift corrections were implemented [4]. The images were acquired using Siemens 3T Trio system. A phantom of water container and syringes each filled with different concentrations of standard gadolinium contrast agent and ferumoxytol, as well as a syringe filled with oil were imaged (Figure 1A). Concentration ranging from 1/4 to 1/64 were chosen as a 1/64 concentration of [Gd] corresponds to a single dose injection of Magnevist injected at 4.0 ml/sec assuming a normal cardiac output of 5 L/min. The frequency shift was varied from +0 Hz to +1525 Hz in 11 evenly spaced intervals.

Results:

Frequency shift of water varied with the concentration of gadolinium. Higher concentrations of Gd caused more shift from the Larmor frequency of water. Figure 1(B,C) shows unsubtracted images of a series of syringes with varying [Gd] were excited at +650Hz and +1300Hz from the Larmor frequency. Water, fat, and other concentrations are completely suppressed resulting in elimination of streak artifact normally associated with radial imaging. Average signal in each Gd concentration was plotted against frequency shift (Figure 2).

Discussion

Fat and water was successfully suppressed using the off-resonance excitation. These results show great potential for angiography without the need for subtraction. The radial sequence allows for sliding window reconstruction, resulting in frame rates high enough for dynamic angiography.

References

[1] Edelman, MRM 2007, [2] Riederer et al MRM 1988. [3] Cashen TA, ISMRM 2006, [4] Peters, et al MRM 2003.

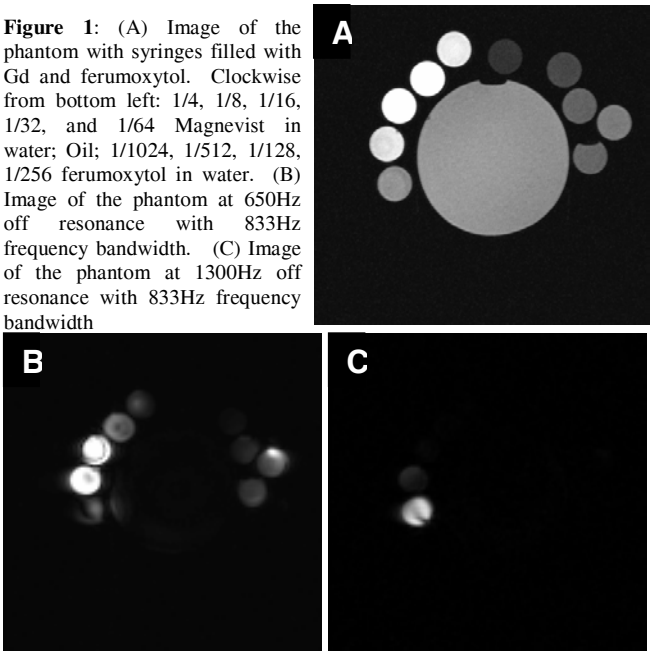

Figure 1: (A) Image of the phantom with syringes filled with Gd and ferumoxytol. Clockwise from bottom left: 1/4, 1/8, 1/16, 1/32, and 1/64 Magnevist in water; Oil; 1/1024, 1/512, 1/128, 1/256 ferumoxytol in water. (B) Image of the phantom at 650Hz off resonance with 833Hz frequency bandwidth. (C) Image of the phantom at 1300Hz off resonance with 833Hz frequency bandwidth

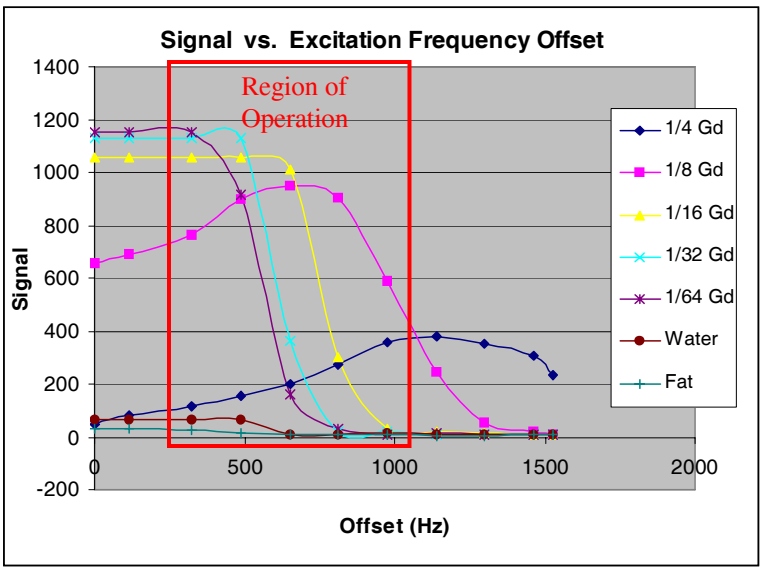

Figure 2: Plot of signal vs. frequency offset for various concentrations of Gd, water, and fat. The +650Hz offset and 833Hz bandwidth corresponds to the red box.