Selective Adiabatic Pulses for T1-Weighted Contrast Enhancement at 0.38 T

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Introduction: Inversion recovery (IR) pulse sequences have been extensively used for T_1-weighted contrast enhancement [1-3]. Inversion pulses used are either selective amplitude modulated pulses, or non-selective and selective adiabatic full passage (AFP) inversion pulses. The disadvantage of the AM inversion pulses lies in their narrow bandwidth (BW) and high peak powers, whereas non-selective AFP pulses have limited B_1 homogeneity across a thick slab in 3D imaging. To achieve accurate spin inversion, selective AFP inversion pulses, such as hyperbolic secant (HS) pulses, have been used for IR pulse sequences [4,5]. Adiabatic excitation pulses have been known for enhancing sensitivity and uniformity in the presence of B_1 inhomogeneity [6]. Thus, sensitivity enhanced T_1-weighting is expected if a selective adiabatic inversion pulse is coupled with a selective adiabatic excitation pulse as long as the nonlinear phase dispersion generated by the two pulses cancels with each other. In this study, we employed a selective HS_1 inversion pulse coupled with a selective HS_1 excitation pulse in a 3D IR-GRE pulse sequence for T_1-weighted contrast enhancement.

Methods: One phantom was imaged on a 0.38 T Resonex electromagnet with a Tesla gradient coil (80 mm ID, 1 mT/m/A gradient strength) using a home-made solenoid coil (42 mm ID). The phantom consists of a glass tube (24 mm OD) containing four small glass vials (6 mm ID). The big glass tube was filled with 9% NaCl dH_20 solution, whereas the small vials were filled with 2, 1, 0.5, and 0.25 mM $MnCl_2$ in 9% NaCl dH_2O solutions, respectively. An isolated beating rat heart (~ 8mm long) perfused with St. Thomas solution containing 1.5 mM free radical (TAM) at a flow rate of 2 mL/min, was also imaged using a smaller home-made solenoid coil (24 mm ID). A 3D GRE pulse sequence from MR Solutions was modified into an IR-GRE3D sequence by incorporating selective AFP HS_1_R15 (BW = 3750 Hz, pulse length = 4 ms, B_1(max) = 2 kHz) and sinc (5 lobe sinc, pulse width = 2 ms, BW = 3 kHz) inversion and excitation pulses into the sequence. The slice selection gradient amplitude for the inversion HS_1 pulse was scaled to $1/\sqrt{2}$ of that for the excitation HS_1 pulse for nonlinear phase dispersion cancellation [7]. T_1-weighted images were obtained using AFP-GRE3D and sinc-GRE3D pulse sequences, respectively. Scan parameters: spectrum width (SW) = 10 kHz, matrix size = 128x128x32, slab thickness = 30 mm, FOV = 40 mm, FOV in slab selection direction (FOV2) = 30 mm, flip-angle (FA) = 90°, TR/TE = 230/14 ms, TI = 200 ms, orientation = transverse, number of averages = 1, scan time = 15m58s. 3D images were also acquired using a GE3D pulse sequence for contrast reference. Scan parameters: SW = 10 kHz, matrix size = 128x128x32, slab thickness = 30 mm, FOV2 = 30 mm, FA = 90°, TR/TE = 230/14 ms, orientation = transverse, number of averages = 1, scan time = 15 m 42 s.

Results: Sample images acquired using two kinds of IR pulses were shown in Fig. 1. Clear signal enhancement was observed using AFP-GE3D pulse sequence in comparison to that of the sinc-GRE3D sequence. For the positively enhanced image of Vial-1 in the phantom (Fig. 1), AFP-GE3D demonstrated greater signal-to-noise ratio (SNR) and longer slab coverage than that of the sinc-GRE3D in the axial direction (Fig. 2). Enhanced T_1-weighted contrast was obtained in heart images using the AFP-GRE3D sequence as demonstrated by the clear boundary between the left ventricle (LV) and the right ventricle (RV) of the heart (Fig. 3).

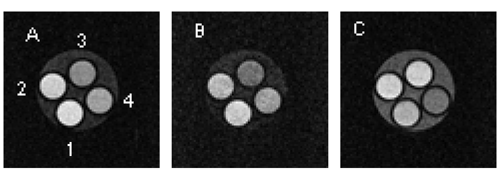

Figure 1. Axial images (image #15 among 32 images) acquired using AFP-GE3D (A), sinc-GE3D (B), and GE3D (C) sequences, repectively.

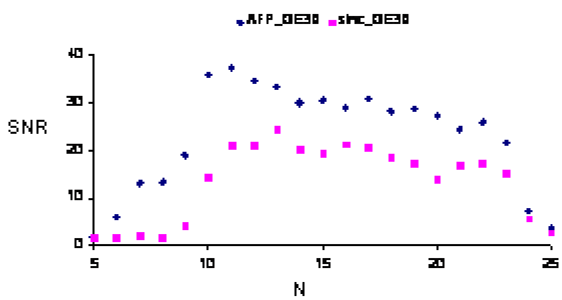

Figure 2. Axial image SNR of Viail-1 as a function of image number (N) across the 3D volume. Noise images of N < 5 and N > 25 were ignored.

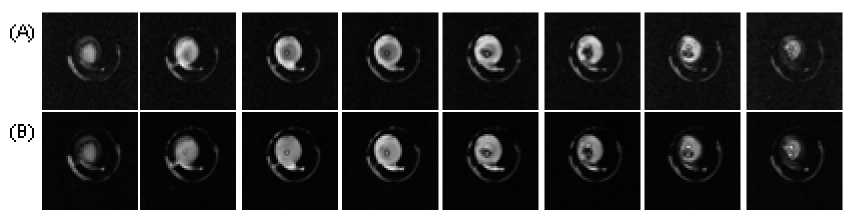

Figure 3. Axial images of an isolated rat heart obtained using AFP-GE3D (A) and GE3D (B).

Discussion: In comparison to amplitude modulated inversion and excitation pulses, signal intensity and T_1-weighted contrast can be significantly increased using selective inversion and excitation AFP pulses. The sensitivity enhancement is attributed to the mutual cancellation of the nonlinear phase dispersion between the selective inversion AFP pulse and the selective excitation AFP pulse.

References and Acknowledgments: [1] Kellman P, et al. Magn Reson Med 2002;47:372-383. [2] Rydberg J, et al. Magn Reson Med 1995; 34:868-877. [3] Foo TKF, et al. Radiology 1994;191:85-90. [4] Mitschang L. Magn Reson Med 2005;53:1217-1222. [5] Klaas P, et al. J Magn Reson 2000;146:58-65. [6] Garwood M, DelaBarre L. J Magn Reson 2001;155-177. [7] Kunz D, Magn Reson Med 1987;4:129-136. The authors thank Dr. Frederick Villamena for supplying the TAM redical, and Dr. Amir Abduljalil for helpful discussions in image processing.