T2-Weighting Enhancement using Pseudo-Echoes Generated by Selective Adiabatic Refocusing Pulses in a CPMG Pulse Sequence

Z. Sun[1]
[1]Davis Heart & Lung Research Institute, The Ohio State University, Columbus, Ohio, United States

Introduction: Selective adiabatic excitation pulses have been used to produce pseudo-echoes using the non-linear phase dispersion of the spins at the echo time [1,2]. With specific image reconstruction methods, improved image quality has been achieved [1,2]. To date, no reports have been published for generating pseudo-echoes using selective adiabatic refocusing pulses in a typical CPMG pulse sequence. In this study, a customized CPMG pulse sequence is developed, which is incorporated with selective adiabatic full passage (AFP) refocusing pulses that alternate frequency sweep (AFS) [3] directions between each of the echoes in the CPMG sequence. The purpose of the study is to increase T_2-weighting in the acquired images using the accumulated non-linear phase dispersion passing through the CPMG pulse sequence.

Methods: T_2-weighted images were acquired from a phantom on an 11.7 T Bruker Avance-500 micro-imaging system, which is equipped with a Bruker gradient coil (ID = 40 cm) and a birdcage transceiver RF coil (ID = 2.8 cm). The phantom consisted of a plastic tube (ID = 15 mm) and three glass vials (ID = 5 mm) forming four regions of interests (ROI). The plastic tube formed ROI-1, which contained a mixture of 50 μM $MnCl_2$ dissolved in 5% agar and 30% volume 5 μm ORGASOL polymer beads. The glass vials were filled with 50, 100, and 150 μM $MnCl_2$ water solutions and formed ROI-2 to 4, respectively. A MSME pulse sequence from Bruker was customized to incorporate an amplitude modulated (AM) selective refocusing pulse (hermite.rfc, bandwidth = 2.7 kHz, pulse length = 1.3 ms), an AFP selective refocusing pulse with single frequency sweep (SFS) directions between each of the CPMG echoes (HS_1, R-factor = 20, B_1(max) = 2.6 kHz, pulse width = 3.5 ms), and an AFP-AFS selective refocusing pulse (HS_1, R-factor = 20, B_1(max) = 2.6 kHz, pulse width = 3.5 ms), respectively. A selective AM excitation pulse (hermite.exc, bandwidth = 2.7 kHz, pulse length = 2 ms) was used in the MSME sequence. Single slice axial images were collected using the customized MSME pulse sequence incorporated with the hermite, SFS, and AFS selective refocusing pulses (TR = 1s, effective TE = 14 – 112 ms in steps of 14 ms, number of echoes = 8, FOV = 40 x 40 mm^2, matrix size = 256 x 256, slice thickness = 2 mm, number of averages = 4, number of dummy scans = 2, scan time = 17 min 4 sec). Images were reconstructed using the quadratic reconstruction point spread function (PSF) [1] in the slice selection direction (z-direction) and the regular 2D FFT in the x, y-directions using Matlab (Version 7.6, Mathworks). Apparent T_2 time constants were calculated from the linear regression of the logarithm of the average signal intensity (ln(SI)) as a function of the effective TE.

Results: Significant lower apparent T_2 time constants were generated using the AFS-MSME sequence than those of the hermite-MSME and the SFS-MSME sequences (Table 1). To further illustrate the increased apparent T_2-weighting, a typical plot of ln(SI) as a function of effective TE for ROI-1 and T_2-weighted images at effective TE = 70 ms are shown in Figs.1 and 2, respectively.

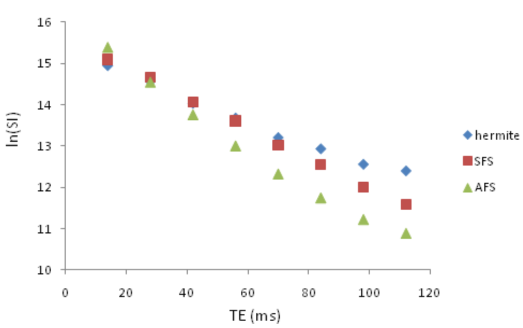

Figure 1. Image signal intensity ln(SI) as a function of effective TE measured using AFS-MSME

Table 1. Apparent T_2 measured for the phantom

Refocusing Pulse	T_2 (ms) ROI-1	ROI-2	ROI-3	ROI-4
hermite	33.7 ± 1.3	33.9 ± 0.8	22.8 ± 0.5	18.7 ± 0.8
SFS	27.1 ± 0.5	29.4 ± 0.7	19.9 ± 0.3	16.3 ± 0.4
AFS	19.1 ± 0.6	20.3 ± 0.6	15.4 ± 0.3	13.4 ± 0.3

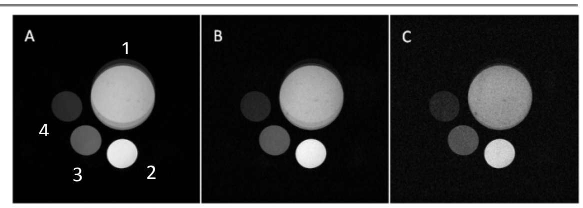

Figure 2. T_2-weighted images acquired using the customized MSME sequence incorporated with (A) hermite, (B) AFP-SFS, and (C) AFP-AFS selective refocusing pulses at effective TE = 70 ms.

Discussion: The apparent T_2 measured using the AFS-MSME sequence is about 40% shorter than that of the hermite-MSME sequence in ROIs-1 and 2, and about 30% shorter than that of the SFS-MSME sequence. About 30% and 20% apparent T_2 shortening were observed in ROIs-3 and 4 using the AFS-MSME sequence than those of the hermite-MSME and SFS-MSME sequences, respectively. The greater apparent T_2-weighting generated using the AFS-MSME sequence in the ROIs containing lower concentrations of $MnCl_2$ suggests that the CPMG pseudo-echo train could be more effective for increasing T_2-weighted contrast in the presence of low concentrations of contrast agents. Improvements to the pseudo-echo signal-to-noise (SNR) ratio could be achieved using other image reconstruction methods [2].

References: [1] J.G. Pipe, Magn. Reson. Med. 33 (1995) 24-33. [2] J.Y. Park, et al, Magn. Reson. Med. 55 (2006) 848-857. [3] Z. Sun, et al, J. Magn. Reson. 188 (2007) 35-40.