Multeslice Gradient Echo CEST Imaging

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INTRODUCTION

CEST, Contrast Enhancement by Saturation Transfer(1) requires RF excitation of an agent at its resonance frequency. This excitation dependence provides unique capabilities. CEST with responsive agents allows quantitation of pH(2,3) and metabolites(4,5). Targeted CEST agents with different targets may be injected together yet imaged separately(6).

Long RF saturation pulses maximize CEST but they slow imaging and require transmitter modification. Breaking the pulse into short sections(7) sidesteps transmitter limits and single shot imaging methods recover speed. Instead, we added short CEST saturation pulses to a 2D gradient echo pulse sequence (Fig 1), one before each observe pulse. CEST pulses spaced less than T1 apart have a cumulative effect. Flexibility in speed, coverage, and S/N of ordinary gradient echo imaging is retained(8). We show that this is practical, produces the same CEST effect in each slice, and, as with 3D methods, S/N increases with coverage.

METHODS

Imaging came from a transmit receive coil 18 cm long x 10 cm D in a 1.5 T Signa (GE Healthcare, Waukesha, WI). Phantom data came from slightly tapered 70 mm long centrifuge tubes containing 0, 20, and 60 mM EuDOTA-(gly)$_4$, which has a chemical shift of 52 ppm. Slices were 5 mm thick on 10 mm centers. FOV 12 cm TE, 5 ms; NEX 2; TR 100 ms per slice. A 128 x 64 matrix required 12.8 seconds scan time per image. CEST pulses were 20000 degrees in 50 ms, making the RF duty cycle 50%.

RESULTS and DISCUSSION

Fig 2 shows z-spectra taken simultaneously from five slices and three samples.

Table 1 shows the CEST effect for several numbers of slices (and therefore repeat times) and observe pulse flip angles. Noise (mean magnitude, empty part of image) was ~8, independent of TR and observe flip.

The pulse sequence of Fig 1 uses the time between short saturation pulses to observe the signal. For one slice, the early acronym FLASH(9), Fast Low Angle SHot is appropriate. Interleaving more slices increases scan time, TR, and sensitivity (see Table), the latter owing to the increased relaxation time between excitations of any given slice. However, during that extra time, an observe pulse directed at water in one slice may excite the CEST agent in another slice. As shown in Fig 3, this would not affect all slices equally. Fig 2 seems free of this inequivalence.

REFERENCES

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Flip	20 mM			
90	24	56	119	215
60	35	84	167	289
45	44	103	189	287
30	57	123	200	255
15	79	122	143	161
10	74	96	103	110
Slices	1	3	7	13

Table 1. CEST effect vs TR and observe flip for 20 mM agent. TR is the number of slices imaged times 100 ms. Effect is signal with off resonant RF minus signal with resonant RF.

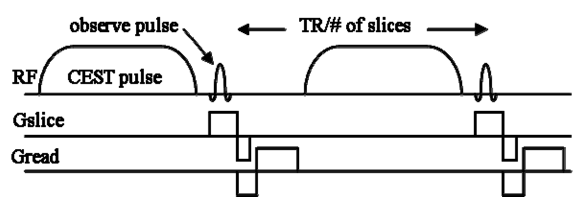

Fig 1. 2D-multislice, gradient-echo, CEST pulse sequence.

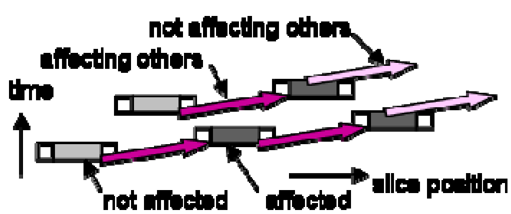

Fig 3. Exciting slices 1, 2, and 3 may induce CEST in slices 3, 4, and 5 but not 1 and 2.

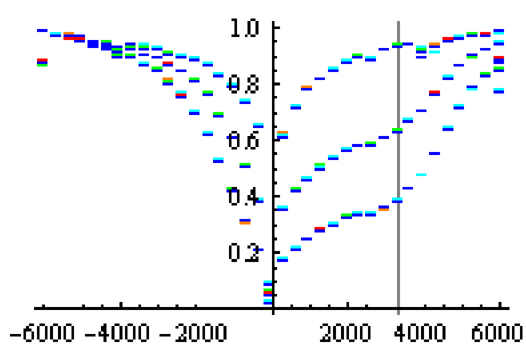

Fig 2. Z-spectra of 5 slices (colors) and 3 agent concentrations (0, 20, 60 mM, top to bottom) taken at once. CEST effect is independent of slice position. Offsets are in Hz.