Magnetization transfer prepared gradient echo CEST MRI at 7 Tesla

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Introduction: CEST MRI is an emerging contrast mechanism that is uniquely sensitive to dilute CEST agents, local pH and temperature, and remains promising for a host of in vivo applications[1-6]. However, the CEST MRI sequence is often implemented with long RF irradiation followed by fast image readout, which requires significant sequence development [7]. In addition, echo planar imaging based acquisition is susceptible to field inhomogeneity-induced distortion, which is particularly severe at high field strength. To address these limitations, our study evaluated the magnetization transfer prepared gradient echo (MTPGE) MRI sequence for CEST imaging [8]. Specifically, we showed that MTPGE MRI was sensitive to the creatine concentration in a creatine-gel phantom, and demonstrated its CEST sensitivity. We also evaluated the relationship between repetition time (TR), flip angle (FA), magnetization transfer saturation time (MTTS), magnetization transfer flip angle (MTFA) and the experimentally obtained CEST effect. We further demonstrated the endogenous amide proton transfer (APT) brain imaging using the optimized CEST MRI sequence.

Materials and Methods: Phantom: Creatine-agarose gel phantom was prepared to optimize MTPGE MRI for CEST imaging. MRI: MRI experiments were conducted using an Agilent 7T animal MRI system. Routine gradient echo MRI parameters were used: TR/TE=26/2.3 ms and FA=20°. We had slice thickness=2 mm, field of view (FOV) =60×60 mm^2, number of average (NSA) =1 and bandwidth=50 kHz. CEST MRI was optimized as functions of TR, FA, MT saturation time (MTTS) and flip angle (MTFA). In addition, MTTS and MTFA were serially varied. The in vivo CEST imaging data were obtained from the brain of an adult male Sprague Dawley rat, following the protocol approved by local institutional ethics committee. Data were processed in Matlab.

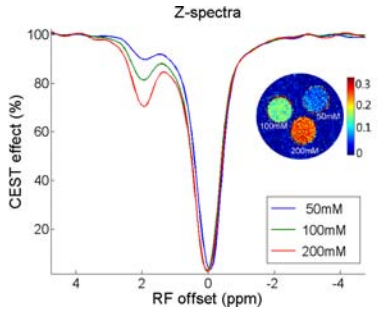

Fig. 1. MTPGE MRI captures CEST effect in the tissue-like creatine CEST phantom. Amine proton exchanged at 1.87 ppm.

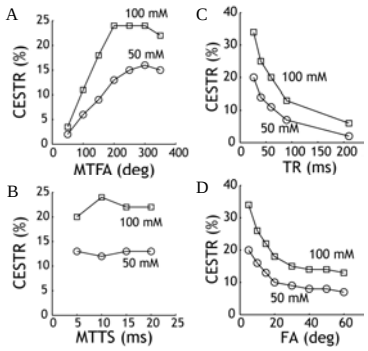

Fig. 2. CEST effect varies with MTFA (A) with little dependence on MTTS (B). CEST effects peak at short TR (C) and low FA (D).

Results and Discussion: Fig. 1 shows CEST Z-spectra from three compartments of varied creatine concentration, 50, 100 and 200 mM, with amine proton CEST effect at 1.87ppm. The CEST effect increased along with the creatine concentration, as expected. We also evaluated four key parameters for optimization (TR, FA, MTFA and MTTS). First, the CEST effect increased with MTFA and peaked at about 200-300° (Fig. 2 A). In addition, CEST effect showed little dependence on MTTS (Fig. 2 B), which was likely because the steady state CEST effect was already reached at the center of k-space. Moreover, the CEST effect strongly depended on TR and FA (Fig. 2 C and D). Because both short TR and low FA are necessary to reduce T_1- relaxation induced loss of CEST effect, CEST effect was significantly higher at short TR and low FA, as expected. The approximately optimal FA appeared to range from 5 to 15° at 7 Tesla. We further obtained in vivo CEST data in rat brains using the optimized MTPGE CEST MRI sequence. The spatiotemporal resolution and sensitivity were sufficient so that the apparent CEST contrast among major brain structures could be well delineated (Fig. 3). Specifically, APT effect was measured using the asymmetry analysis, with the CEST effect being -6.3±1.5%, -7.9±0.8%, -11.4±1.7% and -9.2±0.8% for brain gray matter, white matter, corpus callosum and striatum, respectively. In summary, because the proposed MTPGE sequence can capture CEST effect with little image distortion yet requires no hardware modification and sequence development, it remains promising for translational CEST imaging at high field strength and clinical applications.

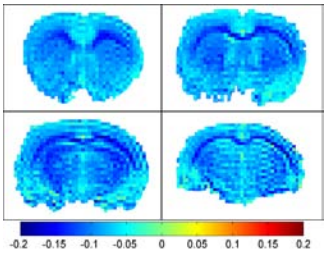

Fig. 6. Preliminary rat brain APT MRI using the optimized MTPGE CEST MRI.

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