Spiral-CEST Encoding with Spectral and Spatial B0 Correction

Sugil Kim[1,2] and Jaeseok Park[3]

[1]*Department of Brain and Cognitive Engineering, Korea University, Seoul, Korea,* [2]*Center for Neuroscience Imaging Research, Institute for Basic Science (IBS), Sungkyunkwan University, Suwon, Korea,* [3]*Biomedical Imaging and Engineering Lab., Department of Global Biomedical Engineering, Sungkyunkwan University, Suwon, Korea*

Introduction

Chemical exchange saturation transfer (CEST), which exploits saturation transfer induced proton exchange and its corresponding, indirect loss of water signals, has been shown to provide a novel contrast mechanism in MRI [1,2]. However, CEST MRI is highly vulnerable to magnetic field inhomogeneities. To address this problem, it often requires multi-spectral acquisitions (z-spectrum), and hence leads to prohibitively long imaging time [3]. In this work, we propose Spiral-CEST encoding with spectral and spatial B_0 correction under the hypothesis that in the presence of magnetic field inhomogeneities spiral encoding induced image blurring in the spatial dimension makes no contribution to a DC frequency shift in the z-spectral dimension due to the spatially, slowly varying field map.

Method

CEST Signal Acquisition: A timing diagram of the proposed Spiral-CEST encoding is shown in **Fig. 1**. Gaussian-shaped RF pulses with the amplitude of 0.7uT (50 ms) were successively applied in the step of off-resonance saturation (3 sec), while single shot spiral acquisition [4] was employed in the step of CEST encoding. Design parameters were: maximum gradient amplitude = 22mT/m, slew rate limit = 150T/m/s, duration = 3000ms. Z-spectrum data were acquired by spiral encoding with off resonant frequency of the saturation RF pulses varying from -5 to +5 ppm with an increment of 0.5 ppm. The imaging parameters were: flip angle = 90°, FOV = $200 \times 200mm^2$, matrix size = 64×64, slice thickness = 2.5 mm, saturation time = 3000 ms, repetition time = 6000 ms, echo time = 4ms, and total imaging time = 2 min.

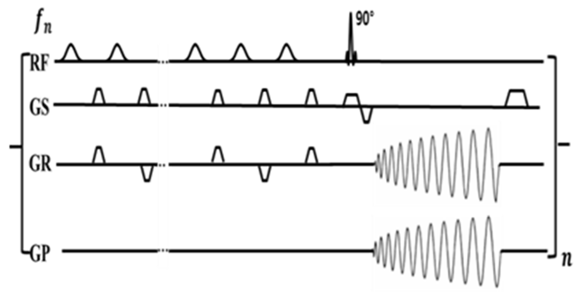

Fig. 1 Timing diagram of the proposed Spiral-CEST sequence

Spatial and Spectral B_0 Correction: Prior to B_0 correction, actual spiral trajectory errors, which result from gradient imperfection and eddy currents, were measured and corrected [5]. Then, convolution-interpolation followed by inverse Fourier transform were performed to produce spatiotemporal images in the x-z dimension that are potentially blurred due to magnetic field inhomogeneities. It is hypothesized that magnetic field slowly varies over the entire spatial dimension and thus off-resonance induced image blurring in spiral encoding does not affect a DC frequency shift in the z-spectral dimension. Given the hypothesis, a spatial field map was estimated by employing the entire, initially blurred images in the spatial dimension and then measuring a DC frequency shift of the voxel intensity profile in the z-spectral dimension using WASSR [3]. With the field map estimated from the analysis of the z-spectrum, spatial B_0 correction in each image was performed using multi-frequency interpolation [6]. With correction of image blurring in the spatial dimension, the initial field map was refined using WASSR, and spectral B_0 correction was performed to eliminate data inconsistency over the spectral dimension that potentially occurred in the previous steps. To investigate the effectiveness of the proposed method against conventional methods, CEST maps and their corresponding z-spectral profiles in a set of data were generated using: a) no correction, b) spectral B_0 correction, and c) spatial and spectral B_0 correction.

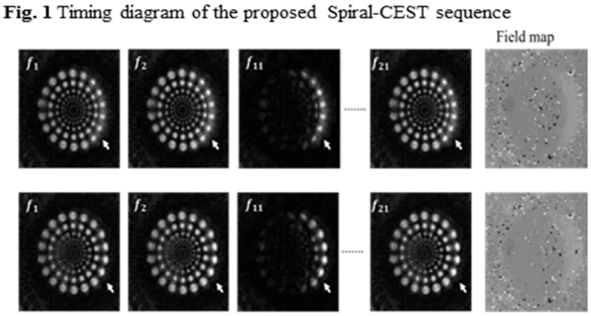

Fig. 2 CEST-weighted images before(top row) and after(bottom row) B_0 correction in the spatial domain using the field map

Result and Discussion

Fig. 2 shows spiral CEST-weighted images before (top row) and after (bottom row) B_0 correction in the spatial domain using the field map estimated from the analysis of z-spectrum. All images in the entire spectral dimension, which suffers from severe blurring before correction, restore spatial resolution after correction. It is noted that the field map estimated from the z-spectrum remains nearly identical before and after B_0 correction, which proves the hypothesis of this work. **Fig. 3** represents that the CEST map yields: (a) severe blurring and (d) inaccurate MTRasym (multiple peaks) for amine in creatine with no B_0 correction, (b) severe blurring but (e) improved MTRasym (single peak at 2 ppm) with spectral B_0 correction, and (c) reduced blurring and (f) accurate MTRasym (single peak at 2 ppm) with spatial and spectral B_0 correction.

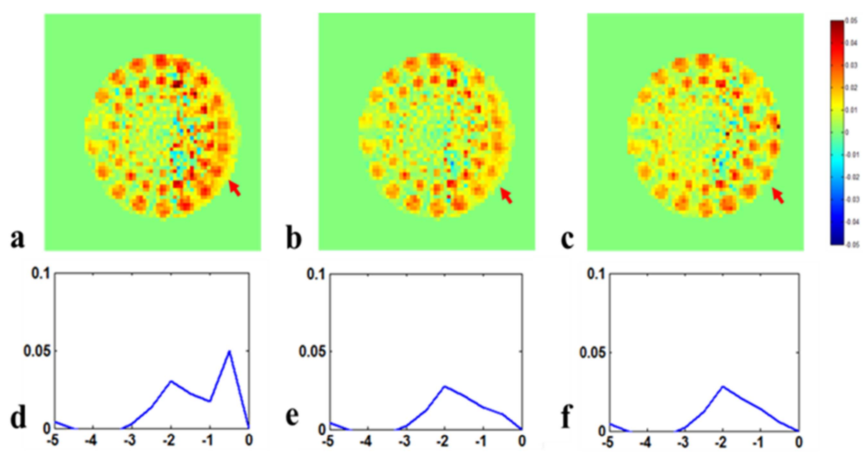

Fig. 3 CEST map (top row) and corresponding MTRasym (bottom row)
(a) no correction (b) spectral B_0 correction (c) spatial and spectral B_0 correction

Conclusion

We successfully demonstrated that Spiral-CEST encoding with spatial and spectral B_0 correction is highly effective in generating proton exchange induced image contrast within potentially clinically reasonable imaging time with no apparent loss of spatial resolution and accuracy.

References

[1] Guanshu Liu et al, NMR BIOMED 26: 810-828(2013) [2] Peter C.M. van Zijl et al, MRM 65: 927-948(2011) [3] Mina Kim et al, MRM 61: 1441-1450(2009) [4] Gary H. Glover, MRM 42: 412-415(1999) [5] Jeff H. Duyn etal, JMR 132: 150-153(1998) [6] Lai-Chee Man et al, MRM 37:785-792(1997)