High Resolution Chemical Exchange Saturation-Transfer MRI at 21.1 T

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Introduction

Chemical Exchange Saturation Transfer (CEST) contrast originates from a loss in the bulk water signal caused by the transfer via chemical exchange of saturated exchangeable protons from other molecules. At high field, CEST contrast is stronger due to longer T_1 (favorable for water exchange) and increased spectral dispersion. CEST-weighted imaging allows for quantitative mapping of the parenchyma, both in healthy and with the devastating intrusion of a glioblastoma[1]. This work explores for the first time the use of endogenous CEST-weighted imaging in healthy control and in a rat glioblastoma animal model at 21.1 T.

Experimental

Experiments were performed at the NHMFL using the 21.1-T magnet. CEST-weighted ^{1}H spin-echo (SE) images (TE/TR=11.5/5000 ms) were acquired with a 200-µm in-plane resolution and 1-mm slice thickness. The CEST preparation consisted of a 400, 10-ms Gaussian-shaped pulse train, with a frequency offset varying between –6 and +6 ppm with 0.2 ppm increments and a B_1 of 1.5 µT. WASSR correction was implemented for center frequency shift[2]. For the glioblastoma model, 100,000 9L glioma rat cells were injected in five animals at 2 mm anterior, 2.5 mm lateral and 3.5 mm deep with respect to Bregma. The animals were scanned at 11 days post transplantation. CEST-weighted images were processed and quantified with a customized MATLAB code to create and display WASSR correction maps, Z-spectra, magnetization transfer ratios (MTR_{asym}) and Lorentzian deconvolved spectra.

Results and Discussion

This work displays the increased biochemical information that can be acquired with CEST acquisitions at 21.1 T. **Fig. 1** shows highly resolved Z-spectra of healthy tissue, revealing strong signals that have not been identified before *in vivo* and likely arising from a Nuclear Overhauser Effect (NOE, black circle). In **Fig. 2**, new unidentified signals can also be identified in tumor tissue (red ROI in inset), with CEST contrast strongest at ~3.5 and ~2.75 ppm (blue and purple circles) arising from amines and amides, respectively. Many other highly resolved and reproducible exchange sites also are visible, which together with significant changes in amide-CEST and NOE-CEST can now identify the tumor and its progression with higher accuracy and sensitivity.

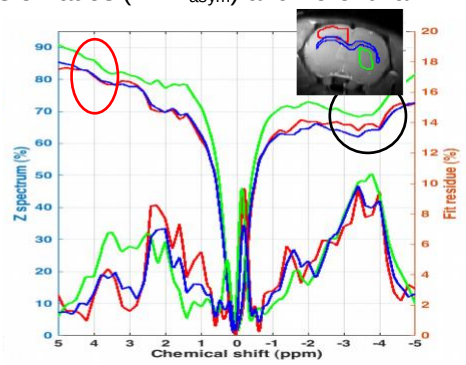

Fig. 1: Highly resolved Z-spectra (top) and deconvolved Z-spectra (bottom) from three different regions as seen in insert. Red and black circles indicate new unidentified exchange sites

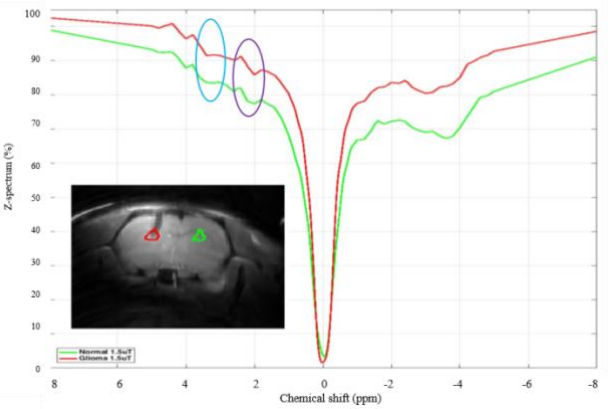

Fig. 2: Highly resolved Z-spectra (top) from tumor (red line) and healthy (green line) tissue as shown in insert. Circles show increased contrast for amines (blue) and amides (purple).

Conclusions

Glioblastomas have a very frequency-specific and strong CEST response around ~3.5 ppm, which together with NOE-CEST and amide-CEST contrast reveals the tumor and its progression over time. CEST-weighted imaging at 21.1 T shows impressive contrast enhancement suggesting a strong dependence with T_1. Ultimately, better interpretation of MRI CEST data should aid in brain tumor diagnosis and monitoring.

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References

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[2] Kim, M., *et al.,* Magn Reson Med, **61**, 1441-1450 (2009).