CEST-MRI at 7 Tesla: implementing multi-pool Lorentzian fitting method for CEST signal analysis in a population of glioma patients

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INTRODUCTION: As the RANO medical imaging criteria categorize tumor responses solely based on Gadolinium-enhanced T1- and FLAIR T2-weighted anatomical images, the lack of knowledge regarding metabolic alteration remains a challenge to derive accurate assessment in cases like pseudo-progression and pseudo-response [1]. Chemical exchange saturation transfer (CEST) has been shown potential to indicate the effects of metabolic alterations resulted from tumor progression, where the amide proton transfer (APT) peak at 3.5 ppm is found to correlated to the mobility of proteins and peptides between tumor and surrounding tissues [2]. MTR asymmetry method is commonly used to extract the APT-weighted effect, yet the specificity of the obtained results is compromised due to presence of other effects such as NOE or MT. In this study, the advanced method of multi-pool Lorentzian fitting [3] was implemented to process the CEST data from a population of glioma patients, where the effects shown on CEST Z-spectrum were each represented by a pool modeled with a Lorentzian function. Compared to the MTR asymmetry method, the Lorentzian fitting approach was able to separate the contrast between APT and NOE effect, thereby providing more specific information regarding protein versus lipid concentration and tumor cellularity.

METHODS: A total of 8 pre-treatment glioma patients went through scans on the 7T Philips Achieva MR system using a 2-channel TX / 32-channel RX head coil (NOVA Medical). A single slice 2D Turbo Field Echo (TFE) sequence was used for the CEST acquisition. The high-resolution scan consisted of a total of 79 frequency offsets sweeping from 20 pm to -20 ppm, with 3 additional offsets at 200 ppm to acquire signal intensity with no saturation for normalization. CEST data was acquired at B1 levels of 0.6 uT and 1.2 uT for each patient. B0 and B1 maps were acquired from the same slice.

The post-processing analysis of acquired CEST data was performed using in-house MATLAB code. For the MTR asymmetry method, the Z-spectrum at each pixel was fitted with smooth spline, corrected for B0 field inhomogeneity, and the asymmetry measurement was taken between 3.3 - 3.7 ppm to extract APT-weighted contrast. For the 4-pool Lorentzian fitting method, the pre-processing of B0 inhomogeneity correction and motion correction was performed. The averaged Z-spectrum across the slice was fitted first, where the fitted parameters were used as initial values for pixel-wise fitting to separate contributions from DS, MT, NOE (at -3.5 ppm), and APT (at 3.5 ppm) effects. The fitted amplitudes for MT, NOE, and APT pools were mapped separately, and the APT map was qualitatively compared to the MTR asymmetry results.

RESULTS: The exhibited CEST contrast for the lesion is consistent across both methods for all 8 patients. The application of pre-processing steps (B0 and motion correction) was found to improve the goodness of fit. Figure 1 attached below showcases a series of anatomical and CEST images for a glioma patient.

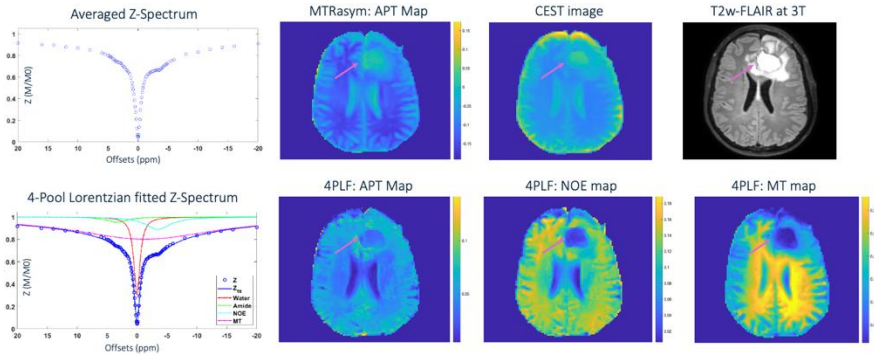

Figure 1. Example results from a glioma patient acquired at B1 of 1.2 uT. The top row includes averaged Z-spectrum across the slice, APT distribution map using MTR asymmetry (MTRasym) analysis, acquired CEST image, and anatomical reference using T2w-FLAIR. The bottom row includes the same averaged Z-spectrum with 4-pool Lorentzian fitting (4PLF), and the APT, NOE, and MT distribution map derived pixel-wise using the 4PLF method.

DISCUSSION & CONCLUSION: Although the high magnetic field strength of the MR system provides stronger CEST signals, the influence of B1 inhomogeneity were found to dominate the CEST effects for some patients. A correction algorithm for B1 field inhomogeneity will be developed using the data acquired at two B1 levels. The study is on-going, and we're expecting more glioma patients to be recruited for CEST baseline scans and follow-ups after treatment.

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