Model-based analysis of GlucoCEST data with a single asymmetry parameter

Chris Lippe[1], Daniel Schache[1], Emily Hoffmann[1], Verena Hoerr[1,2]
[1]*Clinic of Radiology, University of Münster, Münster, Germany.*
[2]*Heart Center Bonn, Department of Internal Medicine II, University Hospital Bonn, Bonn, Germany*

INTRODUCTION

CEST MRI provides high sensitivity but lacks the selectivity needed for precise quantification of individual CEST effects. One promising solution is a model-based analysis approach. Accurate models for CEST and MT effects, based on Bloch-McConnell (BM) equations, have been developed for continuous wave (cw) irradiation scenarios in preclinical research [1]. Nevertheless, these models are frequently too intricate for inverse problem formulation due to the inclusion of non-measurable effects below the noise level.

In this study, we introduce a simplified model that utilizes only a single asymmetry parameter, demonstrating sufficient accuracy for rapidly exchanging pools with small chemical shifts relative to the water resonance, such as hydroxyl protons in physiological conditions. We demonstrate the efficacy of our model for reliable glucose quantification in glucose enhanced CEST (GlucoCEST) experiments [2].

METHODS

Experiments were conducted using a 9.4 T small animal Bruker Biospec MR system, which featured a 72 mm quadrature coil for excitation and a 20 mm surface coil for acquisition. The GlucoCEST data included a highly malignant 4T1 tumor model in sorafenib-treated (n=4) and untreated (n=5) mice [3]. CEST MRI was executed with cw irradiation (3 s saturation; B1 = 1.6 µT; 33 offsets (-5 to 5 ppm) before and after glucose administration) employing a RARE sequence for image acquisition.

We applied an approximate solution to the BM equations from Zaiss et al. [1] and simplified it with the following assumptions: MT effects are symmetric and can be described by a Lorentzian line-shape, glucose exchange rates are significantly higher than its transverse relaxation rates and nutation frequency ω_1. The simplified model with the asymmetry parameter A reads:

$$Z = \frac{R_{1,w} \cdot \Delta\omega^2}{R_{1,w} \cdot \Delta\omega^2 + R_{2,obs} \cdot \omega_1^2 + A \cdot \Delta\omega \cdot \omega_1^2} \Rightarrow \Delta\omega \cdot MTR_{Rex} = \frac{A \cdot \omega_1^2}{R_{1,w}}$$

RESULTS

Figure 1 shows an exemplary tumor image, along with conventional group-wise MTR_{asym} (1-2 ppm) analysis and regression-free model-based asymmetry analysis by calculating the mean $\Delta\omega \cdot MTR_{Rex}$ (1-2 ppm) of GlucoCEST data. Conventional asymmetry analysis using averaged MTR_{asym} demonstrated significantly ($p < 0.05$) higher glucose uptake in tumors of untreated mice. These findings were validated by the proposed model-based analysis. However, it exhibited lower variance and enabled clearer differentiation between the two groups.

DISCUSSION

Model-based analysis with a single asymmetry parameter holds promise for enhancing CEST MRI quantification of fast exchanging pools, for scenarios of changes in one dedicated CEST pool between two acquisitions, such as in GlucoCEST experiments.

CONCLUSION

We introduced a novel single asymmetry parameter model for CEST MRI analysis and demonstrated its accuracy and effectiveness for GlucoCEST quantification.

REFERENCES:

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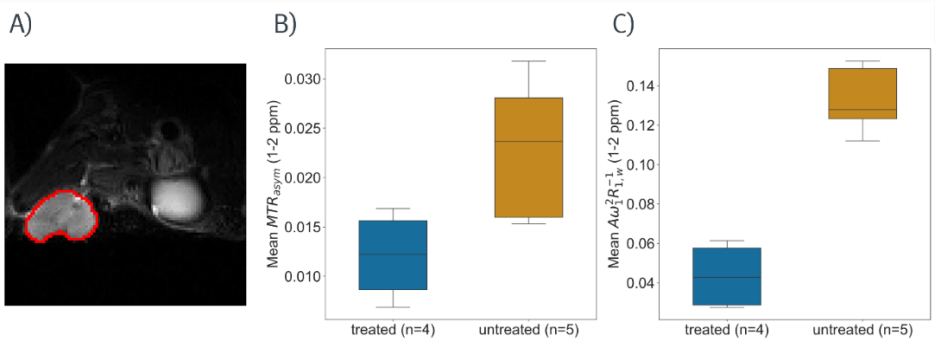

Figure 1: A) Exemplary tumor image with ROI used for masking (red). B) MTR_{asym} analysis C) Model-based analysis