Quasi-steady-state (QUASS) Reconstruction-empowered T_1 Normalization in Apparent Exchange-dependent Relaxation (AREX) Analysis – Application to a Brain Tumor Patient at 3 Tesla

Hahnsung Kim[1,2], Julius Juhyun Chung[1], Jinsuh Kim[2], Ranliang Hu[2], and Phillip Zhe Sun[1,2,3]

[1] *Primate Imaging Center, Emory National Primate Research Center, Emory University, Atlanta, GA*

[2] *Department of Radiology and Imaging Sciences, Emory University School of Medicine, Atlanta, GA*

[3] *Winship Cancer Institute, Emory University School of Medicine, Atlanta, GA*

INTRODUCTION: The apparent exchange-dependent relaxation (AREX) analysis has been proposed as an effective method for correcting T_1 contributions in CEST quantification (1). However, it has been recognized that AREX T_1 correction is challenging when CEST scans are not performed under equilibrium conditions (2). This study aimed to test whether quasi-steady-state (QUASS) reconstruction could enhance the accuracy of the AREX metric under common non-equilibrium scan conditions. We evaluated QUASS CEST and AREX MRI in both phantom studies and a brain tumor patient.

METHODS: We collected images from an 100mM l-carnosine phantom with different T_1 values and a brain tumor patient at 3T whole-body MAGNETOM Prisma scanner (Siemens Healthineers). The MRI parameters for the study were: B_1 = 0.7 uT, offset frequencies from -5 to 5 ppm with increments of 0.125 ppm, satruation duration and relaxation dealys of 1.5/1.5 sec. For the brain tumor patient, imaging readout time = 547 ms, TE = 33 ms, FOV = 220 × 220 mm^2, in-plane matrix = 110 × 110, the number of slices = 8, interleaving slice ordering, slice thickness = 5 mm with 25% slice gap, with fat suppression, 1 average, readout bandwidth = 1976 Hz/pix, and total imaging time is 4 min 50 sec. The CESTR was calucated from the asymmetry analysis, as $\mathrm{CESTR}^{\mathrm{app,QUASS}} = \frac{I^{\mathrm{app,QUASS}}(-3.5\ \mathrm{ppm})}{I_0^{\mathrm{app,QUASS}}} - \frac{I^{\mathrm{app,QUASS}}(+3.5\ \mathrm{ppm})}{I_0^{\mathrm{app,QUASS}}}$, and AREX was calculated as $\mathrm{AREX}^{\mathrm{app,QUASS}} = R_{1w}\cos^2\theta \cdot \left(\frac{I_0^{\mathrm{app,QUASS}}}{I^{\mathrm{app,QUASS}}(+3.5\ \mathrm{ppm})} - \frac{I_0^{\mathrm{app,QUASS}}}{I^{\mathrm{app,QUASS}}(-3.5\ \mathrm{ppm})}\right)$. The QUASS CEST images were reconstructed as published previously (3).

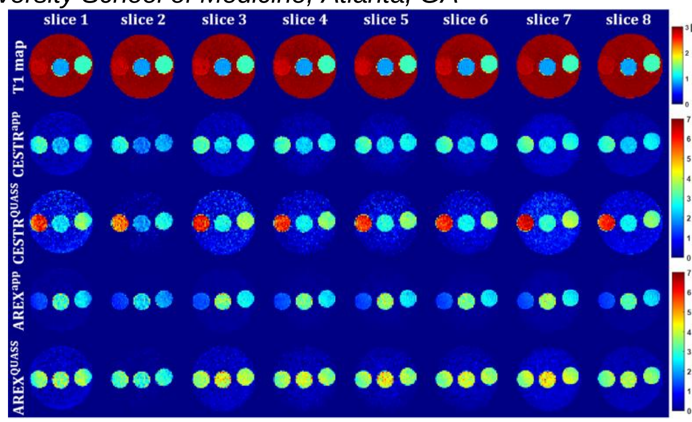

Fig 1. Experimental demonstration of T1 map, apparent and QUASS CESTR maps, and apparent and QUASS AREX maps.

RESULTS and DISCUSSION: In Fig 1, the measured T_1 were 2.80±0.06, 1.30±0.02, and 0.85±0.04 sec for $MnCl_2$ concentration of 0, 15, and 30μM. Although CESTR$^{\mathrm{app}}$, CESTR$^{\mathrm{QUASS}}$, and AREX$^{\mathrm{app}}$ showed dependence on manganese chloride concentrations, AREX$^{\mathrm{QUASS}}$ had little dependence on T_1 variation. The effect of T_1 on CEST and AREX peaks was tested with the generalized linear regression model (Fig 2). Specifically, we have CESTR$^{\mathrm{app}}$ = 1.97 + 0.38·T_1, CESTR$^{\mathrm{QUASS}}$ = 1.23 + 1.66·T_1, and AREX$^{\mathrm{app}}$ = 3.81 - 0.90·T_1. In comparison, the solution form QUASS AREX had no significant correlation with T_1, and we had AREX$^{\mathrm{QUASS}}$ = 3.88 - 0.13·T_1 (P = 0.16). In Fig 3, QUASS AREX showed (red contour) smaller estimated tumor size than the apparent CESTR (black contour). The T_1 value in the black contour area was 1.4 ± 0.1 sec.

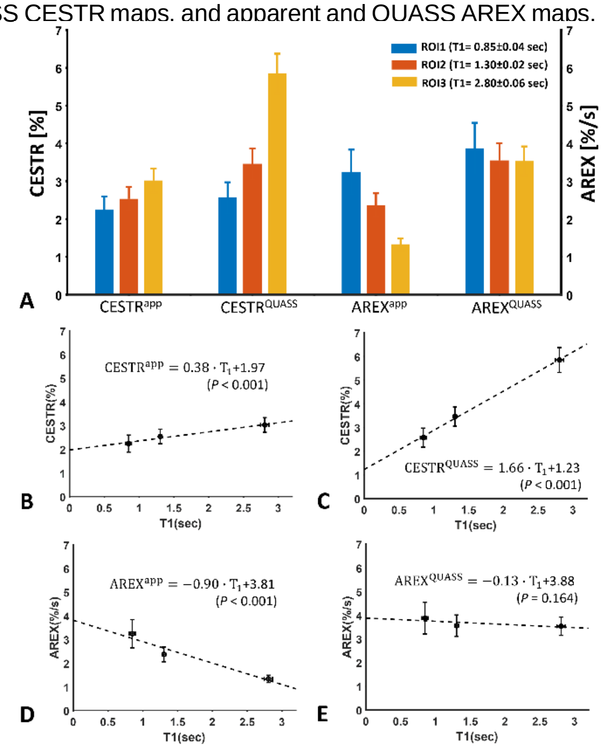

Fig 2. A. Comparison of apparent CESTR, QUASS CESTR, apparent AREX and QUASS AREX between different T1 phantom. B-E. Correlation plots of CESTR and AREX (w/ and w/o QUASS) with T1 values.

CONCLUSION: We demonstrated that AREX analysis benefits from the equilibrium CEST effect reconstructed by QUASS, resulting in improved T1 correction.

REFERENCES: [1] Zaiss M, *et al.* Neuroimage 2015;112:180-188. [2] Sun PZ. J Magn Reson 2021;329:107022. [3] Kim H, *et al.* Magn Reson Med 2022;87(2):810-819.

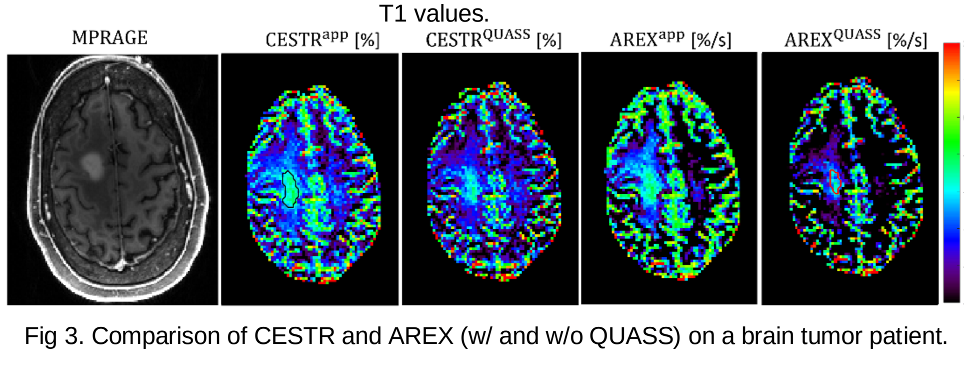

Fig 3. Comparison of CESTR and AREX (w/ and w/o QUASS) on a brain tumor patient.