A New, Polynomial-Based (PARA)CEST Analysis Method with B0 Correction and Increased Sensitivity

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Introduction

Chemical Exchange Saturation Transfer (CEST) MRI is rapidly becoming a popular tool for many *in vivo* imaging applications such as stroke, cancer, and metabolism [1-3]. However, the analysis of CEST imaging data has been limited for many studies which have utilized simple 2-point subtraction techniques to quantify the CEST effect which is susceptible to significant errors from both B_0 and B_1 variation. We have developed a new polynomial fitting technique to quantify the chemical exchange from CEST spectra. This technique models the positive and negative halves of the CEST spectra individually and then determines the net CEST effect by integrating the area difference between the model curves. This new polynomial fitting technique allows for accurate B_0 correction and is inherently less sensitive to experimental factors, such as B_1 variation, that can broaden the CEST peaks.

Methods

We used our rapid and sensitive FISP-CEST technique [4] to acquire CEST spectra for phantoms of bovine glycogen at various concentrations (TR/TE=1.8/0.9ms, 50x100ms Gaussian pulse train, centric encoding, 81 images/spectra). The CEST spectra were first corrected for B_0 inhomogeneities by fitting the direct water saturation (~0ppm) to a 15th order polynomial. After applying the frequency shift, the positive half (green solid line in Fig. 1) and negative half (blue solid line in Fig. 1) of the CEST spectra were fitted to separate 15th order polynomials. The overall CEST effect from the glycogen samples was then calculated by symmetrically projecting the negative curve into the positive frequency range (C(f) = C(-f), blue dashed line) and integrating the difference between the curves (red area in Fig. 1).

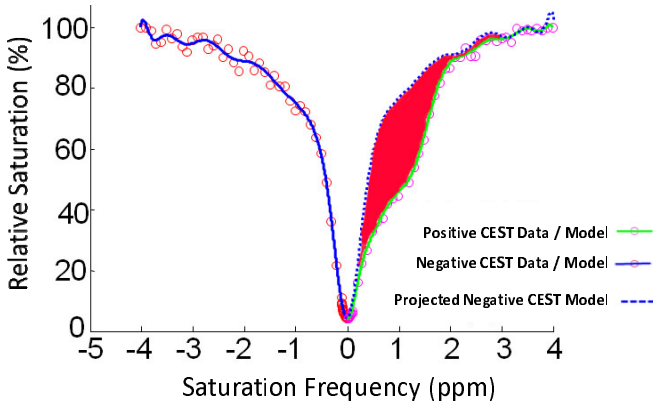

Fig. 1: Polynomial fitting of glycogen CEST spectrum from 100mM glycogen phantom showing the raw CEST data (red circles) and the 15th order polynomial models for the positive (green solid line) and negative (blue solid line) halves of the spectrum. The negative model is analytically projected into positive frequency range to calculate the net CEST area between the curves (in red).

Results

Because of good shimming, the polynomial fits produced relatively small B_0 frequency shifts (±0.4ppm) for this initial phantom study. After fitting the positive and negative portions of the B_0-corrected spectra, the CEST effect was calculated as the area between the curves. The overall CEST effect was also observed to increase with increasing glycogen concentration (50-200mM) and CEST saturation power (Fig. 2). Importantly, the CEST area appears to show better delineation between 100mM and 200mM samples than peak CEST effects and is nearly linear with concentration at B_1=2uT.

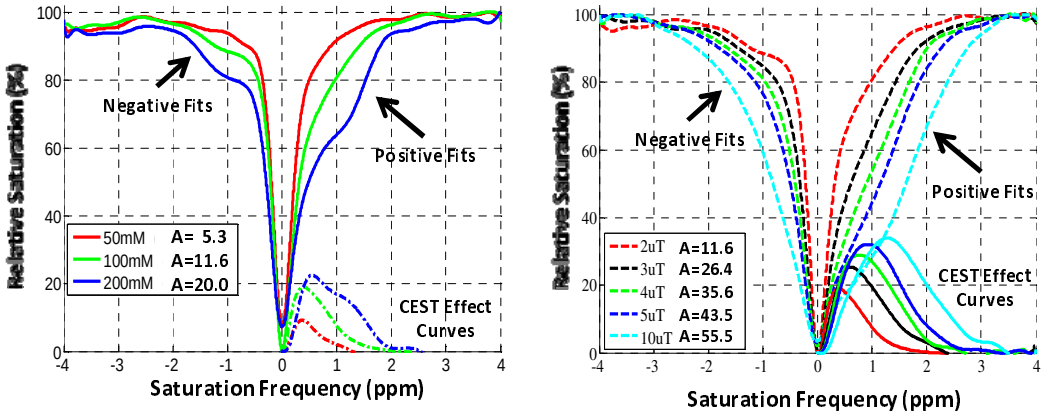

Fig. 2: Polynomial curve fits to glycogen CEST spectra. Note the increasing CEST areas (A) with both increasing glycogen concentration (left, B1=2 μT) and CEST saturation power (right, 100mM glycogen).

Discussion

In this study, we present a new analysis method based on polynomial fitting to efficiently and sensitively quantify chemical exchange effects from CEST spectra. Our initial results with glycogen phantoms show effective B_0 compensation and enhanced sensitivity to glycogen in comparison to simple 2-point subtraction methods. In addition, this polynomial fitting technique is less sensitive to B_1 variations as the CEST effects are integrated over a range of saturation frequencies rather than a single frequency. This methodology has been demonstrated with the known glycogen CEST effect but is readily adaptable to any CEST or PARACEST imaging application for sensitive and accurate quantification.

References

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