Improving Amide Proton Transfer Imaging with Dual Echo B_0 Mapping for Field Inhomogeneity Correction at 3T

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Introduction

Amide proton transfer (APT) imaging is a Magnetic Resonance Imaging (MRI) methodology which detects water signal suppression due to nuclear magnetization transfer between protons of free tissue water and the saturated water-exchangeable amide groups of endogenous mobile proteins and peptides [1, 2, 3]. APT has been developed to detect the over-expressed proteins and peptides in brain tumors for evaluating tumor malignancy and inhomogeneity [4]. B_0 inhomogeneity can pose a significant problem for analyzing APT images since the contrast difference is only a few percent. Conventionally, a CEST spectrum with multiple offsets is corrected by matching the water resonance frequency with the lowest signal intensity. This will give rise to a long scan and result in lower resolution and SNR. In this study, we propose a new method using B_0 mapping [5] and fewer data points which will lead to approximately one third of the current scan time and thus higher resolution.

Material and Methods

MRI Image Acquisition The scans were performed on a 3T MRI system (Achieva, Philips) using an 8-channel SENSE head coil for RF transmission and reception. Nine eggs submerged in a water filled container were used. The pre-saturation pulse was composed of a train of sixteen 1800º block pulses with a pulse length of 31ms. A single slice TSE sequence was applied with TR/TE=6100/62ms, TSE factor=53, matrix=160x160, FOV=160x160mm^2, slice thickness=6mm, NSA=1. Higher-order shimming was employed. A CEST spectrum was acquired (33 offsets from 8ppm to –8ppm in an interval of 0.5ppm). Additionally, a B_0 map was obtained by acquiring two phase images with off-centered echo time difference of 1ms using the same image resolution and NSA=6. The acquisition time for the B_0 map was 4.4s and total scan time was 3min and 38s.

Conventional Analysis The saturated water signal resulted from APT effects can be separated at 3.5ppm based on asymmetry analysis of the CEST spectrum around the water resonance frequency. To quantitatively analyze the data, MTR asymmetry was determined by $MTR_{asym}(3.5ppm)=S_{sat}(-3.5ppm)/S_0-S_{sat}(+3.5ppm)/S_0$. The CEST spectrum with 33 frequency offsets were fit by a least-square polynomial with the degree of 12 in IDL (ITT, CO) using both an ROI-wise and a pixel-wise analysis. Based on generated coefficients, the CEST spectrum was interpolated into 16001 offsets with an offset resolution of 0.001ppm for ROI-wised analysis and 1601 offsets with an offset resolution of 0.01ppm for pixel-wised analysis. B_0 correction was done by assuming the actual water frequency (0ppm) to be at the frequency with lowest signal intensity.

Proposed Analysis Only 10 data points of CEST spectrum (4.5, 4, 3.5, 3, 2.5ppm and –2.5, –3, –3.5, –4, –4.5ppm) were chosen. Data points from 4.5 to 2.5ppm and those from –2.5 to –4.5ppm were fit separately using a least-square polynomial fit with the degree of 3 in IDL and two curves were generated. Based on the resulted coefficients, the two curves were interpolated into 3001 offsets from 5 to 2ppm and –2 to –5ppm separately with an offsets resolution of 0.001ppm. The shift of water resonance frequency was determined by linearly fitting the obtained phase map against the difference of the off-centered echo time and converting the result units into ppm, then the fitted two curves were shifted based on the results. MTR asymmetry parameters were calculated after B_0-map correction. Five ROIs were drawn in egg white and four in latebra using both methods.

Results

Fig. 1a shows a CEST spectrum with ROIs in egg white with the conventional in black and the proposed method in red. Curves were corrected by fitting the lowest point as water resonance frequency (conventional method) and shifting the curve referred to the acquired B_0-map (proposed method), and the original data points were plotted without correction. Fig. 1b shows the MTR_{asym} curve from 0ppm to 7ppm. The suppressed signal at 3.5ppm in CEST spectrum and the increase of MTR_{asym} reflect the APT effect. For the CEST spectrum, the two curves correspond to each other (Fig. 1a) and the peak of MTR_{asym} curve with proposed method is closer to the amide proton resonance frequency of 3.5ppm (Fig. 1b). The difference in MTR_{asym} between the peak and the point corresponding to 3.5ppm is smaller with the proposed method.

MTR_{asym} are 9.6% ± 0.8% with the conventional method and 10.6% ± 0.7% with the proposed method in egg white and 7.4% ± 0.9% and 7.8% ± 1.0% in egg latebra. The difference of MTR_{asym} at 3.5ppm determined with both methods is maximum 1ppm. $MTR_{asym}(3.5ppm)$ encoded color maps with the conventional (Fig. 2a) and the proposed method (Fig. 2b) are shown. High amide proton levels are visible in both the egg white and the latebra. Artifacts in the water of the phantom (Fig. 2) are caused by the dielectric properties of water.

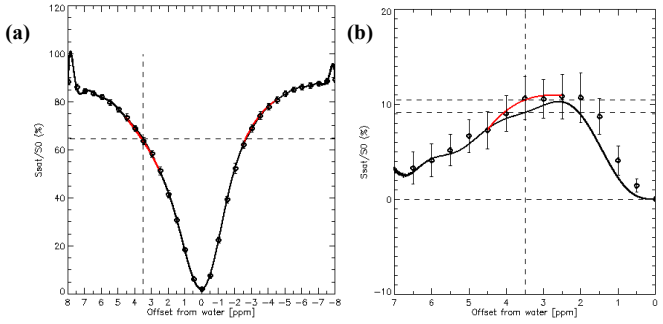

Figure 1a) CEST spectrum and **b)** MTR_{asym} curve in egg white with conventional (black) and proposed method (red). The peak of the red MTR_{asym} curve in is closer to 3.5ppm (amide proton resonance frequency) than the black curve.

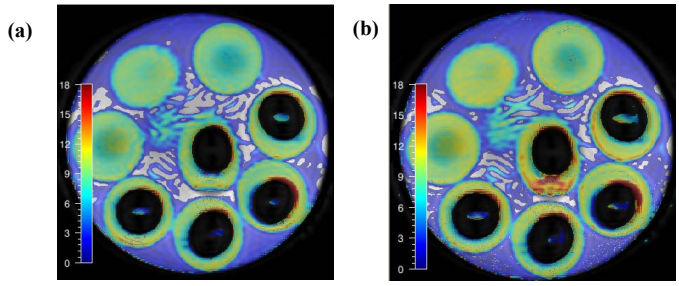

Figure 2a) $MTR_{asym}(3.5ppm)$ encoded color maps with conventional and **b)** proposed method. High amide proton levels are visible in both the egg white and the latebra. MTR_{asym} is generally larger with proposed method which is consistent with the curves in Figure 1.

Discussion and Conclusion

The proposed method for APT using dual echo B_0 mapping offers a more accurate MTR_{asym} curve shape and thus a better determination of the water resonance frequency. This allows a better MTR_{asym} calculation. This study suggests that the proposed method can be used in the future to distinguish tissues with different mobile amide proton concentration by using fewer data points and a shorter scan time.

References

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