Amide Proton Chemical Exchange Saturation Transfer at 9.4 T with Optimized RF Transmit Field through B_1 Shimming

Christian C. Mirkes[1,2], Jens Hoffmann[1], G. Shajan[1], Rolf Pohmann[1], and Klaus Scheffler[1,2]

[1]*High-Field MR Center, Max Planck Institute for Biological Cybernetics, Tübingen, Germany,* [2]*Department for Biomedical Magnetic Resonance, University of Tübingen, Tübingen, Germany*

Introduction

Mobile endogenous proteins and peptides, having concentrations only in the millimolar range, can be efficiently detected via chemical exchange saturation transfer (CEST) based on exchanging amide protons with water molecules. Employing higher magnetic field strengths enables a better discrimination of the amide proton transfer (APT) effect in the Z-spectrum. However, the concomitant B_1 field inhomogeneity at ultra-high fields renders quantification much harder. In this initial work, B_1 shimming [1] was used to achieve a homogenous saturation for the acquisition of amide proton CEST spectra in the human brain at 9.4 T.

Methods and Materials

The measurements were performed on a Siemens (Erlangen, Germany) 9.4 T whole-body MR scanner. A 16-element dual-row transmit coil array combined with a tightly fitting 31-channel receive array [2] were used for radio frequency (RF) transmission and reception, respectively. B_1 shimming was performed by adjusting the relative phase of the current to the independent coil elements. The single channel field maps required for calculating the optimal phase configuration were obtained in a separate scan session.

Data Acquisition: CEST spectra for six transversal slices were acquired in 15 min with an interleaved multislice gradient-echo pulse sequence [3] for one healthy volunteer, who provided informed consent prior to the measurement. The spatially non-selective saturation was performed by a Fermi pulse with a duration of 25 ms, a nominal flip angle of 300°, and a repetition time of 60 ms. A centric-in reordering allowed acquiring the outer *k*-space lines while the CEST effect built up. Other imaging parameters were: TE 2 ms, TR 120 ms, FOV 192x174 mm^2, resolution 3 mm isotropic, flip angle 10°, GRAPPA acceleration factor 2. The frequency range from -5.5 ppm to +5.5 ppm was covered uniformly by 121 individual measurements. In addition to that, one set of reference images (S_0) was acquired without saturation. The different measurements were executed without any pauses between them. However, each measurement started with several seconds of dummy pulses in order to prepare the magnetization. Following the approach of the “water saturation shift referencing” (WASSR) [4] method, the same sequence with a lower B_1 value (10%) was used to determine the absolute water resonance frequency by acquiring 29 images with frequency offsets evenly distributed between -1.0 ppm and 1.0 ppm. In order to assess the effectiveness of the B_1 shimming, the transmit field was mapped with a slab-selective AFI sequence [5].

Data Analysis: A maximum-symmetry algorithm [4] was used to determine the water resonance frequency shift due to B_0-inhomogenity and to assign the correct center frequency to the CEST spectra on a pixel-by-pixel basis. The magnetization transfer ratio asymmetry (MTR_{asym}) was calculated using equation (1). As described in [6], apparent APT and nuclear Overhauser effect (NOE) maps, termed APT* and NOE*, were calculated from the signal, *S*, at three different offset frequencies as given by equations (2) and (3).

$$\mathrm{MTR}_{\mathrm{asym}} = \left\{ S\left(-3.6\mathrm{ppm}\right) - S\left(3.6\mathrm{ppm}\right) \right\} / S_0 \quad \textbf{(1)}$$

$$\mathrm{APT}^* = \left\{ \frac{S\left(3.0\ \mathrm{ppm}\right) + S\left(4.2\ \mathrm{ppm}\right)}{2} - S\left(3.6\ \mathrm{ppm}\right) \right\} / S_0 \quad \textbf{(2)}$$

$$\mathrm{NOE}^* = \left\{ \frac{S\left(-5.0\mathrm{ppm}\right) + S\left(-2.0\mathrm{ppm}\right)}{2} - S\left(-3.5\mathrm{ppm}\right) \right\} / S_0 \quad \textbf{(3)}$$

Results

B_1 shimming allowed to reduce the field (Fig. 1a) inhomogeneity ($\mathrm{std}(B_1)/\mathrm{mean}(B_1)$) to about 17% in the imaged slices, while still being efficient enough to produce the desired saturation. The MTR_{asym} maps (Fig. 1b) are negative due to the NOE at upfield frequencies (e.g. -3.6 ppm) and show a clear contrast between white and gray matter. The contrast in the apparent NOE maps (Fig. 1c) is much less pronounced. The APT* values (Fig. 1d) range between 1% and 2%, whereby they are slightly higher for gray matter than for white matter. Due to the only faint center brightening effect, no correction for B_1 inhomogeneity was applied to the maps.

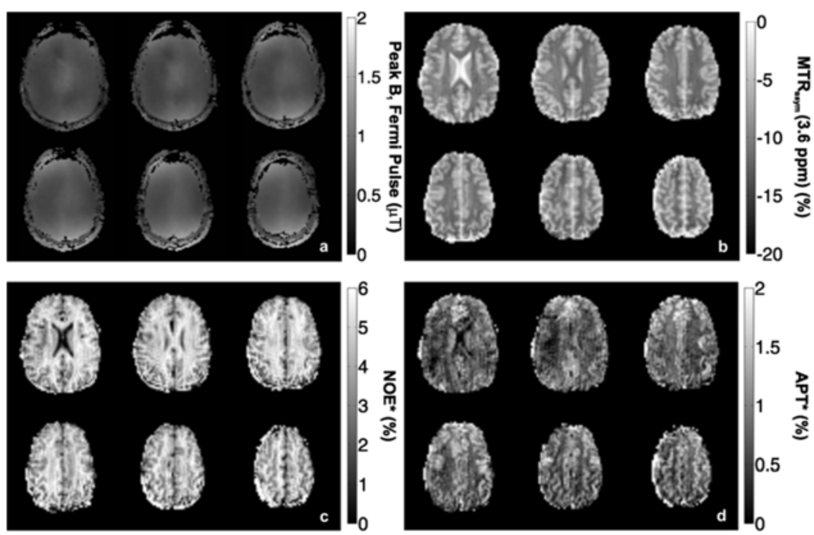

Figure 1. a: Peak B_1 of the Fermi pulse after B_1 shimming. **b:** MTR_{asym} maps (3.6 ppm). **c:** Apparent NOE maps. **d:** Apparent APT maps.

Discussion and Conclusion

We have shown that it is possible to obtain amide proton CEST spectra *in vivo* at ultra-high field strength. As posterior correction of CEST spectra for B_1 inhomogeneity is difficult, shimming effectively improves the quantifiability of the obtained spectra. Further experiments are necessary to assess the stability and reproducibility of the results.

References

[1] MRM (2006); 56:1274–1282. [2] Proc. Int. Soc. Mag. Res. 20 (2012) p.308 [3] MRM (2010); 63: 253–256. [4] MRM (2009); 61:1441-1450. [5] MRM (2007); 57:192–200. [6] Jin et al. *High field MR Imaging of APT Effect and NOE*. MRM (2012)(early view).