^{1}H NMR Spectroscopy in the Human Brain *in Vivo* at 9.4 Tesla: Initial Results

D. K. Deelchand[1], P-F. Van de Moortele[1], G. Adriany[1], P. Andersen[1], K. Ugurbil[1], and P-G. Henry[1]

[1]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States

Introduction

In vivo proton NMR spectroscopy is an invaluable tool that allows non-invasive detection and quantification of a wide range of biochemical compounds in the brain tissue. Higher field strength is advantageous for spectroscopy due to increased signal-to-noise and increased spectral dispersion. These gains may be partially mitigated by increased RF inhomogeneity, increased T_1 and decreased T_2 relaxation times as well as an increased susceptibility effects. Nonetheless it was shown that the precision of quantifying metabolites in human occipital lobe at 7 T is greatly improved compared to 4 T [1]. Here we report the first ^{1}H NMR spectroscopy results in the human brain *in vivo* at 9.4 T.

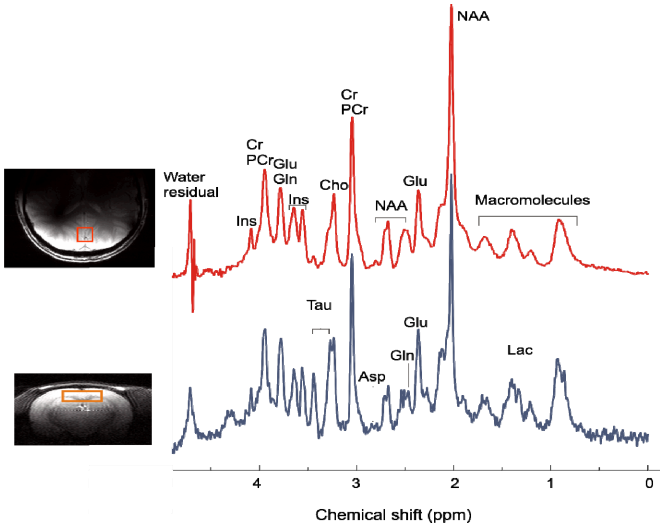

Figure 1: Comparison between ^{1}H NMR STEAM spectrum acquired *in vivo* at 9.4 T from the human visual cortex (top, VOI=8 ml, TE=6 ms, NT=64, SNR=200) and rat brain (bottom, VOI=63 µl, TE=2 ms, NT=128).

Methods

Healthy human subjects were studied in a 9.4 Tesla/65cm bore magnet [2] interfaced to a DirectDrive Varian console. A multi channel transmit-receive half-volume RF coil composed of 8 microstrip elements was used. To reduce destructive B_1^+ interferences in the region-of-interest, the relative phase of transmit B_1^+ field was optimized using a fast, local B_1^+ shimming technique recently described [3]. B_0 shimming was performed using a multi-transmit version of FASTMAP resulting in a water linewidth of ~16 Hz. Single-voxel localization was achieved from a 8 mL VOI located in the visual cortex with a multi-transmit STEAM sequence. Water suppression was achieved with VAPOR [4] and outer volume suppression was achieved using multiple slice selective excitation pulses followed by dephasing gradients. Spectral pre-processing was done in Matlab and the resulting summed spectra were analyzed using LCModel.

Results and Discussion

An *in vivo* ^{1}H NMR spectrum of the human brain acquired for ~7 min at 9.4 T (STEAM, TE = 6 ms, TR = 6 s, VOI= 8 ml, 64 scans) (Fig. 1) showed resonances from many metabolites (e.g. NAA, glutamate, total creatine, *myo*-inositol and choline). This human brain spectrum was very similar to a spectrum acquired in rat brain at the same field (Fig.1). The most noticeable difference was the lower taurine resonances in human brain. The SNR in one scan was 35. The absolute concentration of at least 15 metabolites was reliably determined in human brain (CRLB < 15 %) and concentration values were in excellent agreement with previously published data (not shown).

The T_1 relaxation times (Table 1) were slightly increased at 9.4 T compared to 4 T. For example, T_1 of the NAA singlet was 1.78 s at 9.4 T versus 1.63 s at 4 T [5]. In contrast, T_2 relaxation times were significantly shorter at 9.4 T compared to lower fields. For example, the apparent T_2 of NAA-CH_3 was 98 ms at 9.4 T compared to 158 ms at 7 T [4] and 185 ms at 4 T [5].

Finally, the minimum linewidth obtained *in vivo* (with optimal shimming verified by flat B_0 maps) was increased compared to 7 T (Table 2). Line broadening (LB) due to micro-susceptibility effects increased linearly with field strength (Table 2). The minimum linewidth at 9.4 T was larger in adult human brain (12 Hz) than in adult rat brain (9 Hz), consistent with shorter T_2 in human brain.

Metabolites	T_1 /ms	T_2 /ms
NAA singlet	1777 ± 82	98.0 ± 8.4
Total Cr (CH_3 group)	1746± 133	71.9 ± 5.0
Total Cr (CH_2 group)	1030 ± 270	68.3 ± 6.4
Total Cho	1513 ± 153	70.7 ± 7.1

Table 1: T_1 and apparent T_2 relaxation times (mean ± SD) of metabolites measured in the brain of six healthy subjects at 9.4 T measured with STEAM.

Conclusion

We conclude that high-quality, short-echo time ^{1}H MRS spectrum can be measured in the human brain at 9.4 Tesla. The information content of human brain spectra at 9.4 T appears very similar to those measured in rat brain at the same field strength, in spite of the broader linewidth in human brain. Future work will determine whether quantification precision is improved in human brain at 9.4 T compared to 7 T.

References

[1] Tkac et al MRM (submitted); [2] Vaughan et al. MRM 2006; [3] Van de Moortele et al. Intl Symp. on Biomedical MRI and MRS at Very High Fields Germany, 2006 [4] Tkac et al. MRM 2001 [5] Posse et al. MRM 1995.

Acknowledgments

This work was supported by NIH grants: P41 RR008079, P30 NS057091, R01 NS038672 and the Keck Foundation.

B_0 /Tesla	LW /Hz	$(\pi T_2)^{-1}$ /Hz	LB /Hz
4.0	5.5	2.3	3.2
7.0	9.5	3.7	5.8
9.4	12.0	4.4	7.6

Table 2: Susceptibility effect (line-broadening, LB) with field strength. Linewidth (LW) was measured for the total Cr peak at 3.03 ppm. 4 and 7 T data were taken from [4].