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Improved spectral dispersion in proton MR spectroscopy of the neurochemical profile in the rat brain at 14.1 Tesla

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Introduction. Ultra-short-echo time proton MR spectroscopy is capable of providing concentrations of a large number of brain metabolites (neurochemical profile). Measurements at high magnetic fields benefit from higher SNR and increased spectral dispersion. Most in vivo proton spectroscopy at high spatial resolution was to date performed at 9.4 Tesla and to a lesser extent at 7 and 11.7 Tesla. With the recent availability of a 14.1T/26cm scanner it was our aim to establish proton localized spectroscopy in vivo at 14.1 Tesla and to provide a preliminary comparison with measurements at 9.4 Tesla.

Methods. Proton spectra were measured from the brain of adult Sprague-Dawley rats using 9.4 T/31cm INOVA and 14.1 T/26cm VNMRS spectrometers (Varian, Magnex). Home-built 14 mm diameter quadrature coils were used both for RF excitation and signal reception. An ultra-short-echo time (TE/TR = 2.7/4000 ms) SPECIAL spectroscopy method was used, which combines 1D image-selected in vivo spectroscopy (ISIS) in the vertical (Y) direction with a slice selective spin echo in the X and Z directions and provides full signal intensity available in the excited region (1). Identical measurement parameters (RF pulses, gradient amplitudes and sequence timing) were used on both instruments. VOIs of 50-70µl were placed in the same region at both magnetic fields. Field homogeneity was adjusted by FASTMAP (2). Metabolite concentrations were calculated by LCModel (3), including simulated spectral basis sets and spectra of macromolecules measured using inversion recovery technique. Residual signals of metabolites were removed from the spectrum of macromolecules using the HLSVD algorithm (4).

Results and discussion. The FASTMAP shimming resulted in water and creatine linewidths of 12-13 and 11 Hz at 9.4 T, and 17-18 Hz and 15 Hz at 14.1 T, respectively. Compared to spectra at lower fields (5,6), the most prominent change detectable at 14.1 T was narrowing (in ppm) the spectral lines of GABA, Glu and NAAG in the range of chemical shifts from 1.8 ppm to 2.6 ppm (Fig. 1). Several low-intensity peaks were discernible in the spectral region from 3.5 ppm to 4.2 ppm, which were assigned to Lac (at 4.11 ppm), Glc (3.85 ppm) and GPC (3.67 and 3.87 ppm) (Fig.1, inset). Moreover, additional resonances ascribed to NAA, GPC and PCho at 4.38, 4.31 and 4.27 ppm were detected for the first time in vivo due to the effectively narrower bandwidth used for water suppression. Mean metabolite concentrations at each field were calculated from 5 rats each (Table 1). Despite an excellent overall agreement, it was of interest to note that the concentrations of Ala, GPC, GABA, Gly and NAAG were consistently higher at 14.1 T. This was ascribed to improved separation of spectral lines at 14.1 T, which in turn improves characterization of these compounds in ^{1}H spectra.

Conclusions. We conclude that increasing magnetic field strength to 14.1 T improves spectral resolution in ^{1}H NMR spectroscopy and allows the detection of new resonances in vivo in rodent brain.

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References

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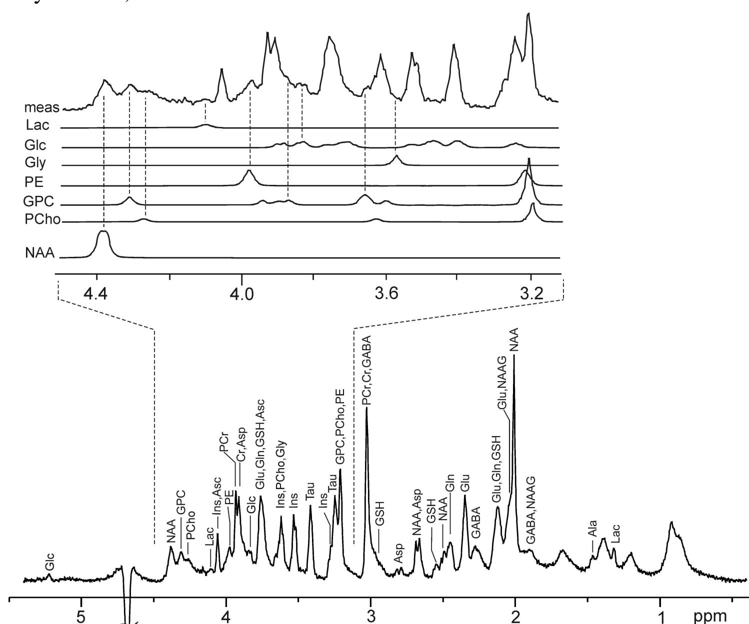

Fig.1. A 14.1 T spectrum (320 averages) of a rat brain measured from a VOI of 4×3×4 mm^3. The expanded region shows the LCModel fit of small peaks from 3.2 to 4.4 ppm. The peak of NAA at 4.4 ppm is partially saturated by the water suppression pulses.

Table 1. Comparison of mean metabolite concentrations measured in rat brain at 9.4 T and 14.1 T, respectively

Metabolite	Concentration ± SD (mmol/kg)	
	9.4 T	14.1 T
Alanine (Ala)	**0.37 ± 0.15**	**0.63 ± 0.12**
Aspartate (Asp)	1.7 ± 0.5	1.9 ± 0.2
Phosphocholine (PCho)	0.47 ± 0.16	0.32 ± 0.05
Glycerophosphocholine (GPC)	**0.33 ± 0.10**	**0.87 ± 0.04**
Creatine (Cr)	3.9 ± 0.5	4.0 ± 0.4
Phosphocreatine (PCr)	4.5 ± 0.4	4.3 ± 0.4
γ-Aminobutyrate (GABA)	**1.1 ± 0.2**	**1.5 ± 0.2**
Glutamine (Gln)	3.0 ± 0.6	2.8 ± 0.5
Glutamate (Glu)	9.8 ± 0.6	10.3 ± 0.9
Glutathione (GSH)	1.0 ± 0.1	1.3 ± 0.2
Glycine (Gly)	**0.50 ± 0.16**	**0.81 ± 0.14**
Glucose[1] (Glc)	1.2 ± 0.8	2.3 ± 0.2
myo-Inositol (Ins)	5.9 ± 0.4	6.2 ± 0.3
N-Acetylaspartate (NAA)	9.2 ± 1.0	9.3 ± 1.1
Taurine (Tau)	6.1 ± 0.7	6.0 ± 0.5
Ascorbate (Asc)	1.2 ± 0.5	1.4 ± 0.4
N-Acetylaspartylglutamate (NAAG)	**0.4 ± 0.2**	**1.0 ± 0.2**
Phosphoethanolamine (PE)	2.1 ± 0.2	2.2 ± 0.5
Lactate[1] (Lac)	1.4 ± 0.5	0.73 ± 0.14

[1]Concentrations of glucose and lactate vary significantly with physiology; therefore, their values cannot be reliably compared.