Proton T_1 and T_2 relaxation times of human brain metabolites at 3 Tesla

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Introduction
Reasonable estimates of relaxation times of brain metabolites are important for accurate quantitation of MR spectra, for optimizing measurement protocols, for absolute quantitation in single voxel MR spectroscopy and in quantitative spectroscopic imaging. Although relaxation times of metabolites in proton MR spectra of human brain *in vivo* have been subject of several studies, T_1 values for 3 Tesla have not yet been reported and only one T_2 study was presented in one of the previous ISMRM meetings (1). Accuracy of the obtained relaxation times is affected by a superposition of a large number of spectral lines belonging to various metabolites, and by broad signals with relatively short T_1 and T_2 which are present as an underlying baseline. Another factor complicating determination of the T_2 relaxation times is evolution of spectral multiplets during the echo time. In this work, T_1 and T_2 relaxation times at 3 T are reported for proton resonances of several brain metabolites. Possible sources of systematic errors of the obtained relaxation times are identified and procedures for their significant reduction are proposed.

Methods
Ten relaxation measurements were done with the VOIs localised in the occipital gray (GM) or white (WM) matter. Experiments were performed on a 3 T Bruker MEDSPEC system using a 10 cm planar surface coil as a transmitter/receiver. A VOI of 2´2´2 cm^3 was selected in the brain of healthy subjects using the STEAM sequence with TR = 6 s and TM = 60 ms. B_1 insensitive water suppression was achieved by a modified SWAMP method (2,3). For determining T_1 values, an inversion recovery technique was used with an additional 30 ms hyperbolic secant full passage pulse (offset -250 Hz relative to the water resonance) preceding the localisation sequence. At least five inversion times (TI) were chosen in the range from 150 ms to 1650 ms. Equilibrium values of signal intensities were read from the spectra without inversion. The short echo time (TE) of 9 ms was used in most measurements, except for two series of spectra with TE of 50 ms in GM and WM, respectively. The T_1 values were calculated from semilogarithmic plots of (I_{eq}-I_{TI}) versus TI. The T_2 values were obtained from slopes of semilogarithmic plots of I_{TE} versus TE using the spectra with TE from 50 to 250 ms.

Results
The calculated T_1 relaxation times are summarized in Table 1. At short TI values, recovery of the creatine methylene peak at 3.92 ppm was faster while it slowed down for the longer TI values. When the measurement was performed with TE = 50 ms, the semilogarithmic plot of the data for the Cr(3.92) line was linear. The calculated T_1 of about 900 ms matched well the short T_1 component found in the experiments with TE = 9 ms. For measuring the T_2 relaxation times, the spectra with TE = 9 ms could not be used for the calculations as they contained substantial amounts of the macromolecular components and/or *J*-coupled multiplets of the other metabolites. When TE > 50 ms spectra were used in the calculation, linearity of the semilogarithmic fits was satisfactory. Our results and the previously published relevant data are shown in Table 2. Note the general trend of decreasing T_2 relaxation times with increasing B_0.

Discussion
The T_1 relaxation times obtained are similar to those found by Frahm et al. (4) at 1.5 T and by Hetherington et al. (5) at 4.1 T. We assume that, in analogy with the relaxation of aqueous protons, the lower T_1 values in WM compared to GM reflect the higher degree of orientation anisotropy of macromolecular structures in WM and the corresponding increase in the efficiency of the dipolar relaxation mechanism. In accordance with previous reports (5,6), no clear correlation between metabolite T_1 and B_0 has been observed. A possible explanation is that the major metabolite lines in the spectrum are formed by nonexchangeable protons and, compared to water protons, their interaction with the pool of less mobile protons of macromolecules is reduced. The T_2 values match previously observed decreasing trends with increasing static magnetic field (5,6).

References
1. Barker, P.B., Hearshen, D.O., Boska, M.D., *Proc. 5th ISMRM Annual Meeting*, 1997, p. 484.
2. de Graaf, R.A., Nicolay, K., *Magn. Reson. Med.* 40, 690. 1998.
3. Mlynárik, V., Gruber, S., Starcuk, Z., Starcuk, Z. Jr., Moser, E., *Magn. Reson. Med.* 44, in press.
4. Frahm, J., Bruhn, H., Gyngell, M.L. et al., *Magn. Reson. Med.*11, 47, 1989.
5. Hetherington, H.P., Mason, G.F., Pan, J.W. et al., *Magn. Reson. Med.* 32, 565, 1994.
6. Posse, S., Cuenod, C.A., Risinger, R., Le Bihan,D., Balaban, R.S., *Magn. Reson. Med.* 33, 246, 1995.

Table 1. Mean values of proton T_1 relaxation times (in seconds ± SE). [a]Values calculated for TI up to 800 ms

	Occipital GM, 3T, this work	Occipital WM, 3T, this work	Occ.lobe, 1.5T, Ref.4	Parietal GM, 4.1T, Ref.5	Parietal WM, 4.1T, Ref.5
NAA(2.01)	1.47±0.12	1.35±0.12	1.45	1.27±0.14	1.26±0.15
Glu(2.35)	1.27±0.10	1.17±0.08	-	-	-
Cr(3.03)	1.46±0.07	1.24±0.10	1.55	1.49±0.15	1.43±0.23
Cho(3.22)	1.30±0.06	1.08±0.06	1.15	1.11±0.14	1.07±0.15
Ins(3.57)	1.23±0.09	1.01±0.09	-	-	-
Ins(3.66)	1.19±0.07	0.93±0.11	-	-	-
Glx(3.75)	1.20±0.10	0.96±0.20	-	-	-
Cr(3.92)	0.97±0.07[a]	0.87±0.11[a]	1.05	-	-

Table 2. Mean values of proton T_2 relaxation times (in milliseconds ± SE)

	Occipital GM, 3T, this work	Occipital WM, 3T, this work	Semiovale WM, 3T, Ref.1	Occipital lobe, 1.5T, Ref.4	Parietal GM, 4.1T, Ref.5	Parietal WM, 4.1T, Ref.5
NAA(2.01)	247±19	295±29	210±20	450	227±27	233±27
Cr(3.03)	152±7	156±20	150±40	240	140±16	141±18
Cho(3.22)	207±16	187±20	180±40	330	189±25	167±20
Cr(3.92)	116±9	141±16	-	190	-	-