Proton spectroscopy of human brain at 3T and 7T: signal-to-noise ratio, spectral linewidth and relaxation times

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Introduction

With the availability of the improved hardware and techniques, in vivo ^{1}H-MRS can offer new possibilities at higher field strengths, such as 7T. This has the potential for providing higher signal-to-noise ratio (SNR) and/or improved spectral resolution. Recent applications have involved animals, healthy volunteers and brain tumor patients. The purpose of this study was to estimate the T_1 and T_2 relaxation times of choline-containing compounds (Cho), creatine (Cr) and N-acetyl aspartate (NAA) at both 3T and 7T in the human brain to evaluate the effects of relaxation times in long echo time MRS acquisition, to examine the differences in SNR between 3T and 7T and to investigate how acquisition parameters influence the quality of the spectra obtained.

Methods

All the empirical studies were performed using an 8-channel receive-only phased-array coil on a 3T GE Signa scanner running Excite software (GE Healthcare Technologies, Waukesha, WI) and a commercial 8-channel receive-only array with a volume transmit head coil (NOVA Medical, Wilmington, MA) on a GE Excite 7T scanner. Twenty-one volunteers were recruited in the study. The volume of interest (VOI) with the voxel size of 8 cm^3 was localized in the parietal white matter. 2D J-resolved PRESS spectra were utilized to measure T_2 relaxation of metabolites at both 3T and 7T. The TE was incremented from 35 ms to 192.5 ms in 64 steps with an increment of 2.5 ms at 3T, while the spectra was acquired with 48 steps with an increment time of 5 ms starting at TE of 35 ms at 7T. For T_1 studies at 3T, MRS data were obtained at TR=1 s with NEX=4, TR=2 s with NEX=4 and TR=8 s with NEX=2, respectively; for T_1 studies at 7T, MRS data were acquired at TR=2 s, 4 s and 10 s and NEX=1. All the spectral data were acquired with 2048 spectral points and 5000 Hz spectral width at both scanners, processed and quantified as published previously (1, 2). The T_1 metabolic relaxation times were calculated from partial T_1 saturation using a two-parameter least-square fitting routine, and the T_2 was calculated using a single exponential function. The TE-averaged spectra for the comparison of linewidth and SNR were generated using TE starting from 35 ms to 190 ms, spacing of 5 ms, at both 3T and 7T.

Results

An example of the 2D J-resolved data from volunteers acquired at 3T and 7T is shown in Fig 1. Compared with the 3T data, the 7T spectra demonstrated higher SNR. With increased echo time, the signal intensity decay of Cho, Cr and NAA was much faster at 7T compared to 3T. The T_1 and T_2 relaxation values of Cho, Cr and NAA are shown in Table 1. Statistical significance was found for the differences in the T_1 and T_2 values of metabolites between 3T and 7T except for the Cho T_1 value. When corrected for filtering, the estimated linewidths for Cho, Cr and NAA were 0.038±0.006, 0.049±0.005 and 0.053±0.003 ppm at 3T, and at 7T they were 0.065±0.012, 0.071±0.013 and 0.069±0.010 ppm (values expressed as mean±S.D.). The ratios were 1.76, 1.43 and 1.32 at 7 T relative those at 3 T. The SNR from the volunteers are given in Table 2. After corrections for the effects of T_1 and T_2 relaxation values, the SNR between 7T and 3T was 1.53 on average. After multiplying the SNR ratio by the differences in linewidth differences in PPM, the SNR would be 2.25 on average, which is close to the theoretical value of 2.33.

Discussion

This study demonstrated that brain metabolite SNR was improved at 7T relative to 3T, but the increase in SNR observed was less than linear with respect to B0, mostly due to the differences in linewidth. This implies that future studies would benefit from better shimming. The significant differences in relaxation times also suggest that longer TR and shorter TE are beneficial for spectral acquisition at 7T to take advantage of the gain in SNR due to increased B0. The metabolite T_1 and T_2 relaxation times obtained in this study from normal volunteers at 3T and 7T may be helpful for designing future MRS studies that will further improve the sensitivity and specificity of this technique.

	T_1 (s)			T_2 (ms)		
	Cho	Cr	NAA	Cho	Cr	NAA
3 T	1.06±0.11	1.38±0.13	1.38±0.13	170±18	151±15	262±37
7 T	1.11±0.20	1.76±0.19	1.63±0.15	131±16	121±12	170±11
P		**0.002**	**0.003**	**<0.001**	**<0.001**	**<0.001**

Table 1. T_1 and T_2 relaxation times of Cho, Cr and NAA at 3 T and 7 T

	Cho	Cr	NAA
3 T	61±11	65±12	140±25
7 T	64±30	76±34	172±57
SNR 7 T : 3 T	**1.049**	**1.169**	**1.229**
T_1 effects	1.017	1.130	1.087
T_2 effects	1.218	1.203	1.262
7 T : 3 T	**1.30**	**1.59**	**1.69**

Table 2. SNRs of metabolites at 3T and 7T

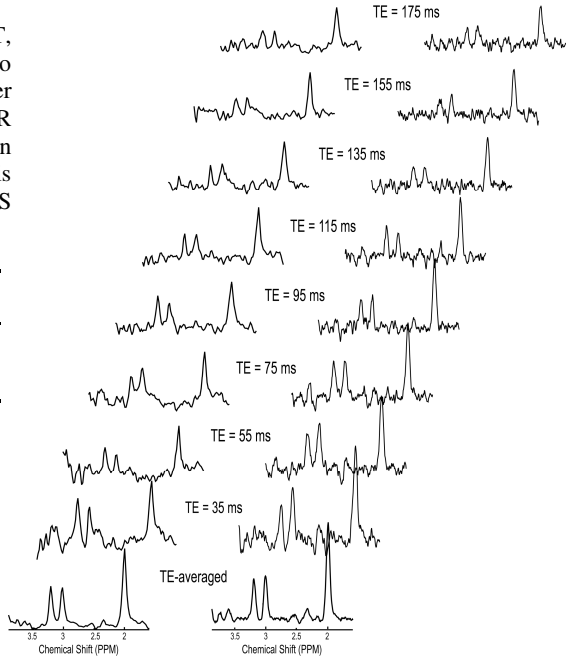

Fig 1. 2D J-resolved spectra for the acquisitions at 3T (left) and 7T (right). The vertical scales of all the spectra were adjusted to equalize the noise level of the different spectra.

References

1. Nelson, SJ. Magn Reson Med 2001: 46: 228-39
2. Li, Y, et al. 14th ISMRM 2006.

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