PRESS Spectroscopy of Glutamate: Effects of Voxel Location and Field Strength

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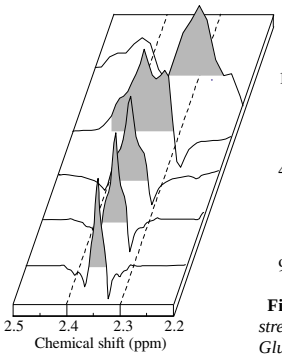
Introduction: Glutamate (Glu) is an important excitatory neurotransmitter in the brain. However, studying this metabolite using in vivo 1H MRS has proven to be difficult, due to significant peak overlap with other metabolites. This is particularly the case at low field and when acquiring data at a short TE, hence Glu has proven to be one of the more difficult metabolites to quantify precisely. While increasing magnetic fields comes with the promise of increased spectral dispersion and SNR, the ability to shim certain parts of the brain at high field may negate these benefits. Moreover, for strongly coupled systems, the increased spectral dispersion can lead to reduced multiplet heights, and field strength variations will affect the timing and available yields. Most high field work has focused on the occipital cortex, where an excellent shim can be obtained (1). In our study, we take a more comprehensive whole brain approach, by considering three different volume placements: occipital lobe, frontal lobe and midbrain, which are known to be increasingly difficult to shim effectively. Using three different experimental field strengths (1.5T, 3.0T and 4.7T) and two theoretical (7.0 T 9.4 T), we first illustrate an optimization the PRESS (2) timings for the best contrast-to-background yield for Glu at each field strength, and then obtain experimental human brain spectra at all three brain locations to fully determine the effects of field strength variation on Glu signal yield.

Methods: The glutamate response to PRESS was first simulated using density matrix calculations (3). Following a technique similar to Yang et al. (4) the optimal timing parameters of PRESS to obtain the best contrast-to-background Glu / Gln / GABA / NAA peak separation at each field were obtained. Both yield and percent contamination were recorded. Using voxels of 3 x 3 x 2 cm^3 placed in the either the frontal cortex, occipital cortex or midbrain locations, PRESS spectra were collected at field strengths of 1.5, 3.0 and 4.7 T from seven volunteers. Spectra were processed using LCModel to quantify the complement of metabolites present.



	PRESS [TE_1,TE_2] ms	% Yield Glu PQ spins Peak Area	% Glu Contamination [Gln, GABA, NAA]
1.5T	[65,65]	20.7	[-0.1, 22.1, -5.4]
3T	[90,18]	79.3	[0.5, 6.3, 1.0]
4.7T	[72,18]	70.6	[-4.5, -2.2, -8.3]
7T	[48,40]	75.3	[0.1, -2.0, -2.0]
9.4T	[20,64]	82.5	[-0.2, -0.6, -1.0]

Figure 1. *Simulated spectra for the Glu PQ-spins at different field strengths. Contamination values are based on mM concentrations of Glu [12.5], Gln [5.5], GABA [1.6], and NAA [11.7].*

Results: Figure 1 illustrates the optimal timings for glutamate at each field strength, the yields focused on the Glu PQ multiplet and the contamination of this target Glu peak . The Table below shows the effect of shim line-width across regions and field strength for 'n' volunteers. Note the dramatic decrease in shim quality in the mid brain. Figure 2 shows occipital brain spectra for each field strength, and highlights the target Glu peak ~ 2.35 ppm.

Conclusions: The optimal timings and yields for PRESS for glutamate vary significantly with field. Using the same 18 mL volume at each field, frontal and particularly midbrain shim is compromised by susceptibility differences arising from air-tissue (frontal) or tissue-iron (mid-brain) effects. In these regions, the SNR gains from higher field are essentially lost due to far poorer shim capability. Nevertheless, the increased spectral dispersion at higher field does offer discrimination benefits.

References: 1. Gruetter ISMRM High Field Workshop, Rome (2008); 2. Bottomley Ann. N.Y. Acad. Sci. 508,333 (1987); 3. Thompson etal Mag.Res.Med. 45,955 (2001); 4. Yang etal Mag.Res.Med. 59,236 (2008).

Field	Region (n)	$FWHM_{NAA}$ Hz (ppm)
4.7T	OC (3)	15.4 +/- 3.1 (0.08 +/- 0.01)
	FC (2)	16.5 +/- 2.2 (0.08 +/- 0.01)
	MB (2)	31.8 +/- 12.4 (0.16 +/- 0.06)
3.0T	OC (4)	5.4 +/- 1.1 (0.04 +/- 0.01)
	FC (4)	6.8 +/- 2.3 (0.05 +/- 0.02)
	MB (4)	9.2 +/- 1.9 (0.07 +/- 0.01)
1.5T	OC (3)	4.8 +/- 0.1 (0.08 +/- 0.01)
	FC (3)	4.5 +/- 1.0 (0.07 +/- 0.02)
	MB (4)	5.2 +/- 0.5 (0.08 +/- 0.01)

Table : *NAA line-widths for each brain region and field strength.*

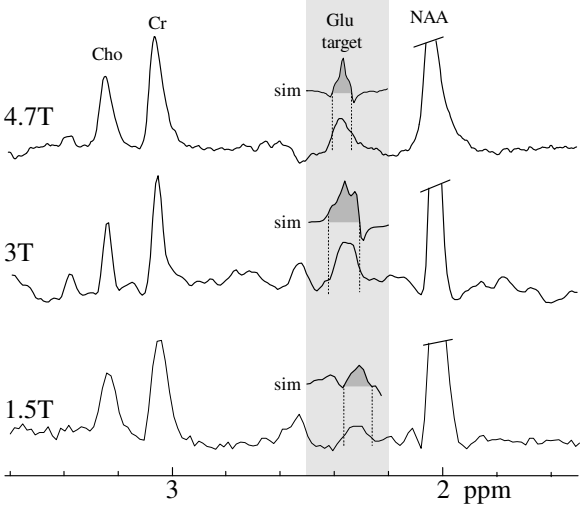


Figure 2 : *Spectra acquired from a 3x3x2 cm OC region of the same volunteer at 3 field strengths, highlighting Glu target band.*