Editing efficiency for macromolecule-suppressed and unsuppressed J-edited GABA spectroscopy

Georg Oeltzschner[1,2] and Pallab K. Bhattacharyya[3,4]

[1]Department of Diagnostic and Interventional Radiology, Medical Faculty, University Dusseldorf, Düsseldorf, Germany, [2]Institute of Clinical Neuroscience and Medical Psychology, Medical Faculty, Heinrich-Heine-University Düsseldorf, Düsseldorf, Germany, [3]Imaging Institute, Cleveland Clinic, Cleveland, OH, United States, [4]Cleveland Clinic Lerner College of Medicine - CWRU, Cleveland, OH, United States

Target audience: Researchers performing edited GABA spectroscopy

Purpose: J-edited magnetic resonance spectroscopy (MRS) for the detection of GABA is based on selective manipulation of J-coupling by frequency-selective inversion pulses (MEGA-PRESS[1]). In an ideal situation, the outer members of the GABA triplet at 3.01 ppm are inverted while the central peak is preserved, yielding a pseudo-doublet after subtraction. The editing efficiency (EE) describes the fraction of the total GABA signal that is preserved in the difference (edited) spectrum. EE is necessary for the calculation of GABA concentrations and is expected to have an upper limit of 0.5 under the assumption of complete elimination of the central peak. On the contrary, real difference spectra exhibit a central peak. The size and shape of the central peak depend on the spatial variation of the refocusing experienced by the GABA spins, which is a factor of the bandwidth and transition bandwidth of the slice-selective refocusing pulses[2]. This work investigates the congruence of different EE calculation methods adopted in literature. EE was calculated with editing pulses placed symmetrically (i) across water resonance as well as (ii) across M4 macromolecule (MM) resonance, which is used to minimize the MM contribution in 3.01 ppm GABA peak[3].

Methods: Phantom (10 mM glycine, 10 mM GABA, room temperature) scans were performed on a 3T whole-body scanner (Siemens Magnetom TIM Trio, Erlangen, Germany) with a 12-channel head matrix coil: 1) MM-unsuppressed (unsupp) MEGA-PRESS, edit pulses at 1.78 (ON-resonance) and 7.62 ppm (OFF-resonance); 2) MM-suppressed (supp) MEGA-PRESS, edit pulses at 1.78 (ON) and 1.38 ppm (OFF) (frequencies were adjusted from in vivo scenario to account for temperature difference). Simulations were performed with VeSPA[4] on a spatial matrix of 20x20 points. Calculations of EE were carried out from the GABA and Gly resonances in the ON, OFF, difference (DIFF) and sum (SUM) of ON and OFF spectra according to different methods (Table 1) with the indices U for MM-unsuppressed and S for MM-suppressed editing. Data analysis by two researchers using different parameters of AMARES on the same data yielded similar patterns for EE values.

Table 1: EE calculation methods and results for the phantom.

Method	Calculation	EE (phantom)
1	$(GABA_{DIFF,\,U} / Gly_{SUM,\,U}) / (GABA_{ON,\,U} / Gly_{ON,\,U})$	0.65
2	$(GABA_{DIFF,\,S} / Gly_{SUM,\,S}) / (GABA_{ON,\,S} / Gly_{ON,\,S})$	0.59
3	$(GABA_{DIFF,\,U} / Gly_{SUM,\,U}) / (GABA_{OFF,\,U} / Gly_{OFF,\,U})$	0.63
4	$(GABA_{DIFF,\,S} / Gly_{SUM,\,S}) / (GABA_{OFF,\,S} / Gly_{OFF,\,S})$	0.75

Results: Table 1 shows the results of different methods of EE calculation. Due to presence of a central peak, all of them exceed the theoretical maximum of 0.5. When calculating EE with respect to the OFF spectra, the difference is particularly striking. Fig. 1 shows that - while the ON acquisitions are identical - the OFF spectra drive the observed differences in EE through size and shape of the 3.01 ppm GABA multiplet.

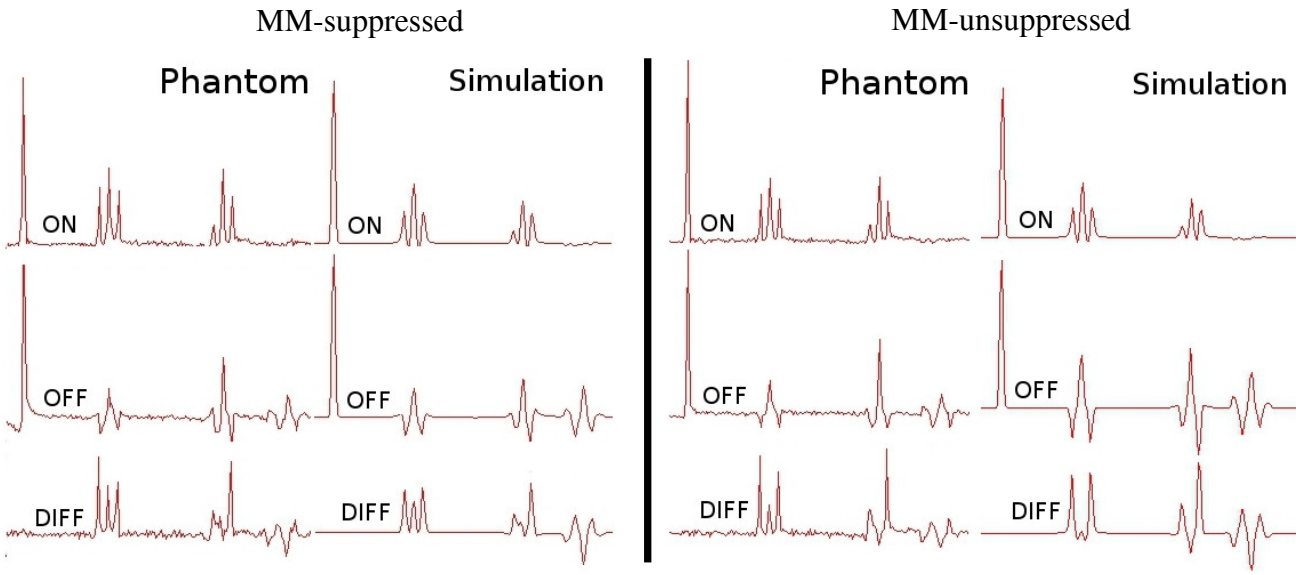

Fig. 1: The shape of the 3 ppm multiplet in the difference spectrum is clearly modulated by the edit frequency of the OFF spectrum.

Discussion: GABA editing is known to be susceptible to inhomogeneities of the spatial localization pulse profile, leading to the presence of a central peak in the difference spectrum[2]. However, localization is identical in both editing schemes and does not explain the variation of the central peak size between MM-suppressed and unsuppressed scheme. While sweeping the edit frequency close to 1.9 ppm drastically influences shape and size of the GABA multiplet[5], the 44 Hz broad OFF pulses at 1.38 ppm should be far enough away in frequency to have any significant effect on phase evolution of the GABA spins[6]. This difference of the central peak between MM-suppressed and -unsuppressed cases might not originate from the inhomogeneities from localization pulses, but rather from the nature of the editing pulses. Uncertainty in EE might arise from the fact that the OFF pattern of neighbouring downward-upward-downward peaks is more prone to fitting variability than the upward-upward-upward pattern showing in the ON and DIFF spectra -- for this reason the data was analyzed by two researchers independently to minimize this variability.

Conclusion: Editing efficiency depends on the set of ON and OFF-resonance frequencies and sequence properties. EE may exceed the theoretical maximum value of 0.5 to a varying extent, depending on the choice of EE reference and the contribution of the GABA 3.01 ppm central peak. It must be measured for every experimental setup, and the study should be calibrated with known GABA concentrations (phantom study) so that differences in method of EE calculation will have no effect on the final GABA quantification.

References: 1. Mescher et al, NMR Biomed, 1998, 266-72; 2. Near et al, Magn Reson Med, 2013, 1183-91; 3. Henry et al, Magn Reson Med, 2001, 517-20; 4. Soher et al, ISMRM, 2011; 5. Harris et al, Magn Reson Med, 941-8; 6. Beall et al, ISMRM Workshop on Ultra-High Field Systems & Applications: 7T & Beyond: Progress, Pitfalls & Potential, 2011.