Very Short Echo Time STEAM Improves Detection of Glutamate at 3-T

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Introduction:

Of the many metabolites detectable by ^{1}H-MRS *in vivo*, glutamate (Glu) is a particular focus. Glutamate is the primary excitatory neurotransmitter in the central nervous system and plays an important role in energy conservation in the tricarboxylic acid cycle. Glutamine (Gln) is the storage form of Glu. At current magnetic field strengths for clinical MRI systems, Glu and Gln present strongly-coupled and overlapping spectral patterns. As a result, Glu quantification *in vivo* is difficult, in spite of being the most abundant amino acid in the human brain. In this study, we seek to determine the optimum parameters for maximizing detection sensitivity of Glu. With the advent of high-field MRI systems, 3-T is rapidly becoming the standard field strength for clinical ^{1}H-MRS. Therefore, following the work of Nilsson[1], we re-examined the TE modulation of Glu and Gln spectra for both STEAM and PRESS localization sequences at 3-T.

Methods and Materials:

Spectra for PRESS and STEAM were simulated assuming strong-coupling conditions at 3-T (frequency = 123.3 MHz) using NMR-SCOPE[2] and the chemical shifts and j-couplings values reported by Govindraju *et al*[3]. The parameters were: for STEAM, TM = 10 ms and TE = 2.5, 3.7, 6, 10, 15, 20, 30, 35 and 40 ms; and for PRESS, TE = 10, 15, 20, 30, 35, and 40 ms. The number of data points was fixed at 2048 and the spectral width to 2.5 kHz. For the STEAM sequence, a two-step phase cycling scheme was implemented. A 0.04-ppm Gaussian apodization was added to each spectrum to approximate conditions *in vivo*. For validation, simulated STEAM spectrum were compared to ^{1}H-MRS data collected from posterior cingulate of three healthy volunteers on a 3-T Magnetom Trio (Siemens Medical systems, Erlangen, Germany) system using a phase rotation with asymmetric RF pulses in localized stimulated echo spectroscopy (PRAISES) technique[4,5]. The sequence parameters were as follows: 16-step phase rotation, 112 NEX, TE/TM/TR = 3.7/10/5000 ms, 819.2-ms acquisition, 2.5 kHz spectral width, 6.0 cm^3 volume, and 2048 complex points. Water suppression was achieved with a commercial implementation of WET sequence (Gaussian RF pulses, 20 Hz bandwidth, and 60 ms separation between consecutive pulses).

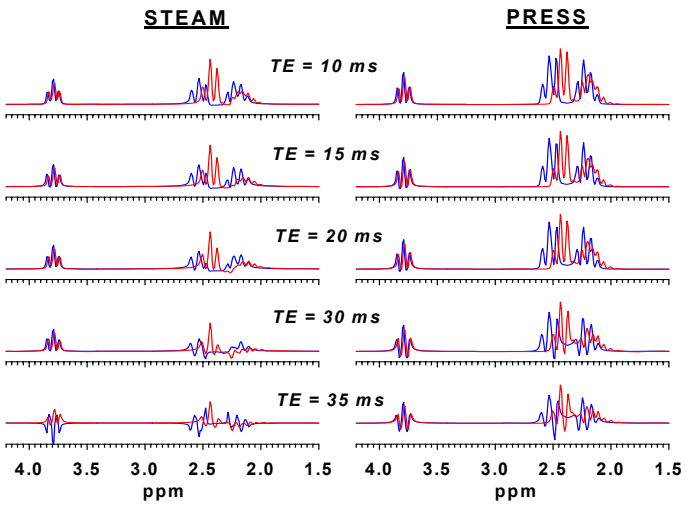

Figure 1. NMR-SCOPE simulation of TE modulated spectra at 3-T for Glu (—) and Gln (—) with a 0.04 ppm of Gaussian apodization.

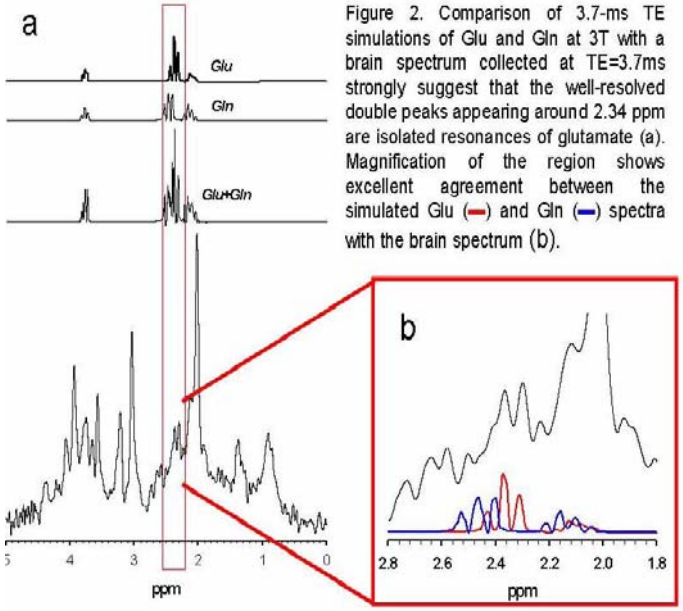

Figure 2. Comparison of 3.7-ms TE simulations of Glu and Gln at 3T with a brain spectrum collected at TE=3.7ms strongly suggest that the well-resolved double peaks appearing around 2.34 ppm are isolated resonances of glutamate (a). Magnification of the region shows excellent agreement between the simulated Glu (—) and Gln (—) spectra with the brain spectrum (b).

Results and Discussion:

With the severity of the overlap between the Glu and Gln spectral pattern increasing with increasing TE, the simulations suggest that neither PRESS nor STEAM is likely capable of accurately resolving the Glu and Gln resonances at standard clinical TEs (20-45 ms) at 3-T (Fig. 1). Without the aid of spectral editing techniques, Glu is best resolved from Gln at very short echo times (VTEs, TE < 10 ms) for both STEAM and PRESS at 3-T. Specifically, at very short echo times, the Glu C-4 multiplet at 2.34 ppm is well resolved from the Gln C-2 multiplet at 2.44 ppm, irrespective of the localization techniques. (Fig.1). Assuming equal concentration of Glu and Gln, the intensity of the C-2 multiplet of Gln is similar to that of the C-4 multiplet of Glu for PRESS. In the case of STEAM, the intensity of the Glu C-4 multiplet dominates that of the Gln C-2 multiplet. Therefore, *in vivo*, where the Glu concentration is expected to be much greater than that of Gln, these simulations indicate that the Glu C-4 multiplet might be more easily identified with a VTE STEAM technique. Although a literature survey revealed that PRESS is the preferred volume localization technique at 3-T, most likely due to the increased SNR, a strong case for STEAM as the optimal technique for the detection of Glu can be made, considering the intrinsic capacity of STEAM for shorter echo times compared to PRESS. Fig. 2 clearly elucidates this hypothesis. We attempted to use a VTE technique, PRAISES, to improve the identification of Glu at 3-T (Fig. 2). The two intense peaks of Glu C-4 multiplet as seen in Fig. 2(b) most likely accounts for the doublet visible around 2.34 ppm in the 3.7 ms TE spectra.

Conclusion:

Simulations suggest that a very short TE STEAM sequence can likely provide improved detection of Glu *in vivo*. The ability to accurately distinguish Glu from Gln might greatly improve the quantification accuracy and precision of Glu *in vivo*, without the use of spectral editing techniques.

References:

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