Improved GABA editing at 3T with real-time motion correction, shim update and reacquisition of MEGA-LASER

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Target Audience: Developers of MR sequences (MRS, motion correction, imaging acceleration); Neuroscientists and clinicians interested in neurotransmitters GABA and Glx.

Purpose. The mechanisms by which GABA modulates brain activity have become a major topic in neuroscience and neuropsychiatric research. MR spectroscopy (MRS) provides the only non-invasive way to measure GABA levels in-vivo, but its low levels and spectral overlap with abundant brain metabolites make this task challenging. In particular, J-difference MRS provides the highest retained signal for in-vivo GABA editing with sequences such as MEGA-PRESS [1,2] or MEGA-LASER [3,4]. However, difference methods are susceptible to subtraction artifacts caused by subject movement and scanner drifts. Low concentration of GABA requires long measurement times, and makes its editing especially prone to this types of artifacts. Here, we show that real-time motion correction combined with dynamic shim update and reacquisition can eliminate artifacts and preserve the GABA signal. In particular, the addition of reacquisition into the correction algorithm is newly demonstrated here for GABA editing.

Methods. All experiments were performed on a whole-body Magnetom Tim Trio 3T MR scanner (Siemens AG, Erlangen, Germany), using body coil for transmit and a 32 channel coil for receive. Measurements were performed in four volunteers (N=4) and a phantom. A navigated single voxel MEGA-LASER sequence was programmed in VB17A scanner software and was used to acquired the GABA edited spectra. Localization was obtained with low power Gradient Offset Independent Adiabaticity GOIA-W(16,4) [5] pulses of 3.5ms and 20kHz bandwidth which have negligible chemical shift displacement error (1.8%). Two 65 Hz Gauss refocusing pulses and 4ms spoilers of 20 mT/m were used for GABA editing. Simulations were used to find the optimum MEGA-LASER editing scheme. A dual echo EPI volume navigator [6] was acquired in each TR before water suppression and was used to update the MEGA-LASER excitation and shims according to the head pose. In addition, a reacquisition scheme was employed for data which are corrupted if motion occurs before the navigator updates the position. Acquisition parameters were: TR = 1700ms, TE = 75ms, (2x)128 averages, total acquisition time 7:23 min:s, voxel size 27 ml. Measurements were performed under static conditions and during motion tasks, with and without real-time correction. Typical nodding and right-left head motions were reproduced across trials. Human subjects were consented with an approved IRB protocol. Spectral fitting and quantification has been done with LCModel [7].

Results. Phantom results are summarized in Figure 1. The MEGA-LASER difference spectra in the static and motion cases employing reacquisition, shim update and motion correction (ReShMoCo) are almost identical. The motion spectra where only shim update and motion correction (ShMoCo), or only motion correction (MoCo), or no correction were performed show subtraction artifacts and contamination with residual signal of creatine and choline. In the volunteer data shown in Figure 2 similar effects of motion can be seen. The ReShMoCo correction provides spectra that show no artifact compared to static spectra. Spectra acquired under motion with ShMoCo or no correction show contamination of the GABA signal with subtraction artifacts. LCModel fitting of spectra indicates that in the presence of subtraction artifacts there is a tendency to underestimate GABA levels by 20-40% with a corresponding increase by 50% of the Cramer-Rao lower bounds.

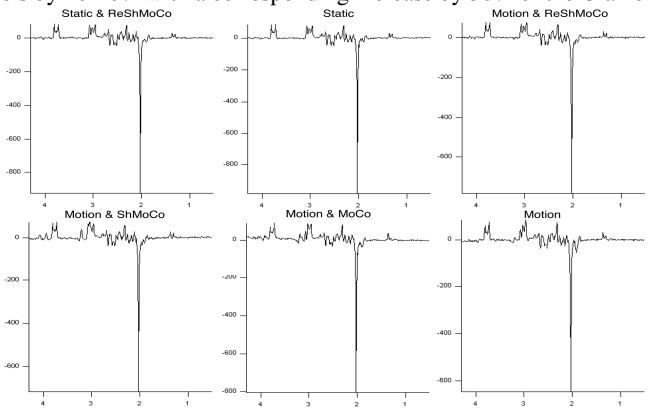

Figure 1. GABA editing with the navigated MEGA-LASER sequence in brain phantom. Spectra acquired with Reacquisition, Shim update, and Motion Corection (ReShMoCo) are almost identical with static spectra. Correction without reacquisition gives inferior results.

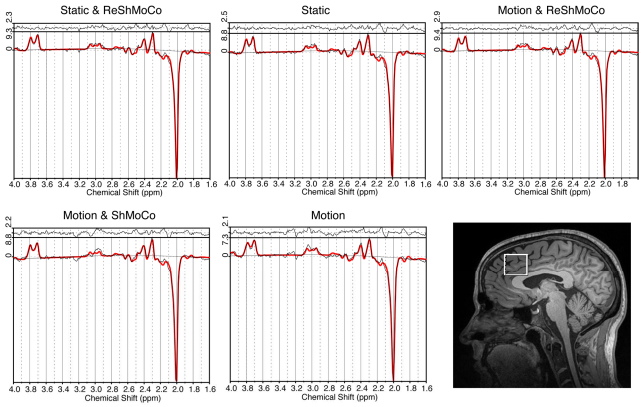

Figure 2. GABA and Glx (glutamate+glutamine) editing in human brain with the navigated MEGA-LASER sequence. ReShMoCo provides the same spectra in the motion case compared to the static case. Artifacts overlapping GABA are visible in motion spectra without ReShMoCo.

Discussions/Conclusion. Our results indicate that J-difference spectral editing might benefit largely from the possibility of motion tracking and updating in real time the localization and shimming. The length of the navigator and update calculation fits within the TR length that is typical of MRS measurements, and hence it does not increase the acquisition time. A relatively small number of averages may be corrupted if motion happens between the EPI navigator and MEGA-LASER excitation, however with reacquisition it is possible to replace and discard the corrupted data. The real-time correction provides several advantages over post-processing methods: i) it can correct for anatomical differences, ii) maintains the editing efficiency by updating the frequency of the narrow band MEGA pulses, and iii) preserves the SNR by reacquiring corrupted data. The bias in quantification of GABA due to motion or scanner instability can be minimized. Further validation and development is underway.

References: [1] Rothman et al, PNAS 1993, 90:5662-6; [2] Mescher et al, NMR Biomed 1998, 11:266-72; [3] Andronesi et al, Science Transl. Med. 2012, 4:116ra4; [4] Andreychenko et al, MRM 2012, 68:1018-2; [5] Andronesi et al, JMR 2010, 203:283-93; [6] Hess et al, MRM, 2011 66:314-23; [7] Provencher, MRM 1993, 30:672-9. **Acknowledgements:** funding from 1K22CA178269-01 (NCI/NIH), Harvard-MIT Bridge Project, S10RR021110, P41 EB015894 and P30 NS076408.