Editing Magnetic Resonance Spectroscopy of lactate at high fields: Improved efficiency by inclusion of FOCI pulses and elimination of co-edited macromolecules

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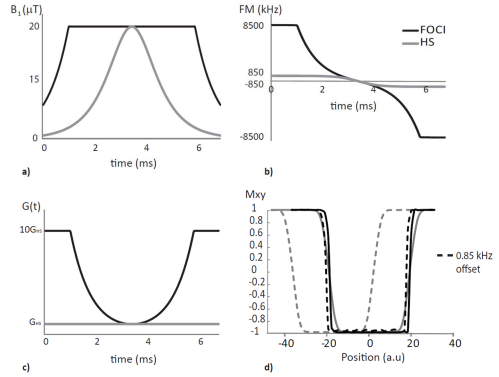

Figure 1: *Modulation shapes of FOCI and HS pulse.*

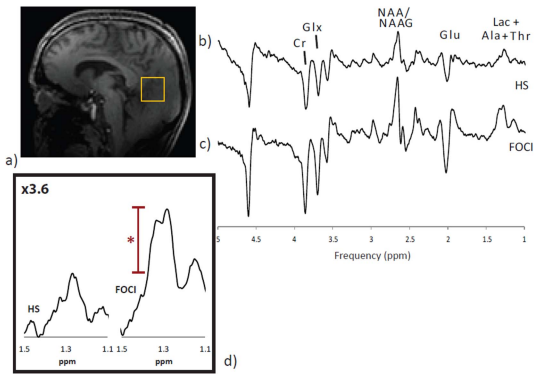

Figure 2: *In vivo MRS of lactate. a) voxel position, volume 27ml. Lactate edited spectrum with HS (b) and with FOCI (c) refocusing pulses.*

Introduction:

Lactate in the brain can be an indicator of various metabolic processes. This weakly coupled spin system can be measured with MRS editing techniques. Considering its low concentration, the use of high field strength can be considered for its gain in SNR. However, the low available B_1^+ field at high fields results in narrow bandwidth refocusing pulses and therefore in large chemical shift displacement errors (CSDE). More importantly, the efficiency of the method is severely reduced due to the increased chemical shift dispersion, even when using adiabatic refocusing pulses. Frequency offset corrected inversion (FOCI [1]) pulses have been suggested to substantially increase the bandwidth of adiabatic pulses. Therefore, in this study, we demonstrate that the boosted gain in SNR of a MEGA-sLASER [2] editing sequence with refocusing FOCI pulses can be used to measure lactate in the human brain at 7 Tesla while excluding the influence of co-edited macromolecules.

Methods:

FOCI pulses were generated based on a hyperbolic secant (HS) pulse. B1 max was 18 μT. A 7T MR scanner (Philips, Cleveland, OH, USA) was used for in-vivo measurements of lactate in the brain of healthy volunteers (MEGA-sLASER (HS or FOCI with f_F = 10, bandwidth 16800Hz), TE/TR=144/6600 ms, 32 NSA respectively). Each acquisition was frequency aligned with the singlet resonance of choline. The acquisitions were averaged after correction and the signal intensities of lactate were compared between the different RF pulses used in the corresponding sequence. To investigate the influence of substantial co-edited macromolecules that overlap with the lactate resonance, editing with a broadband refocusing pulse was compared to editing with a narrowband refocusing (MEGA) pulse. T1-nulling of macromolecules was used to establish an artefact free reference lactate signal (at inherent reduced SNR).

Results and Discussion:

The resulting modulation shapes of the FOCI pulse are shown in Figure 1a, 1b and 1c (black line). For comparison, the modulation shapes of the original hyperbolic secant (HS) pulse are also shown (gray). The spatial inversion profiles for both RF pulses are compared for the spins on- and 850 Hz off-resonance, i.e. chemical shift difference between lactate spin groups (Fig. 1d). Notice the good off-resonance performance of the FOCI pulse that shows only 4.7% shift of the inversion profile compared to the 47% found in the off-resonance inversion profile for the already high bandwidth HS RF pulse.

A substantial signal gain of the lactate peak was found with the FOCI refocusing pulses measurements when compared to the HS refocusing pulses (Fig. 2c and 2b respectively). The lactate/Cr ratios for the FOCI and the HS pulses were 0.19 and 0.34 respectively, resulting in a 75% improved efficiency for the FOCI pulses (Fig. 2d).

While the measurement stability of a narrowband editing pulse (MEGA: FWHM 130Hz) may be questionable, with a broadband editing pulse, more macromolecular resonances are co-edited (Fig. 3a and 3b dark line). In particular, macromolecules at 1.43 and 1.24 ppm (J-coupling to approximately 1.2 and 1.5 ppm respectively) [3] are co-edited which contaminate the detection of lactate. However, with the macromolecule-nulled MR spectra (single inversion, TI=280ms) that cost 40% of the lactate signal, the 75% gain with the FOCI pulses could provide a well detectable and artifact free signal of lactate (Fig. 3a). T1-nulling of macromolecules without editing is not sufficient for an artifact free detection of lactate since the macromolecule nulled metabolite spectrum (Fig. 3b gray line) still shows some resonances around 1.3 ppm.

Conclusion:

The MEGA-sLASER sequence including FOCI pulses for refocusing is an efficient and accurate method for MRS editing of weakly coupled spin systems at high field strengths such as 7T. Combined with T1-nulling of macromolecules, an artifact free detection of lactate is feasible in the human brain that excludes the co-edited macromolecules

References: *[1] Ordidge RJ, MRM 1996;36(4):562-566. [2] Andreychenko A, MRM 2011 [3] Behar KL, MRM 1994 Sep;32(3):294-302.*

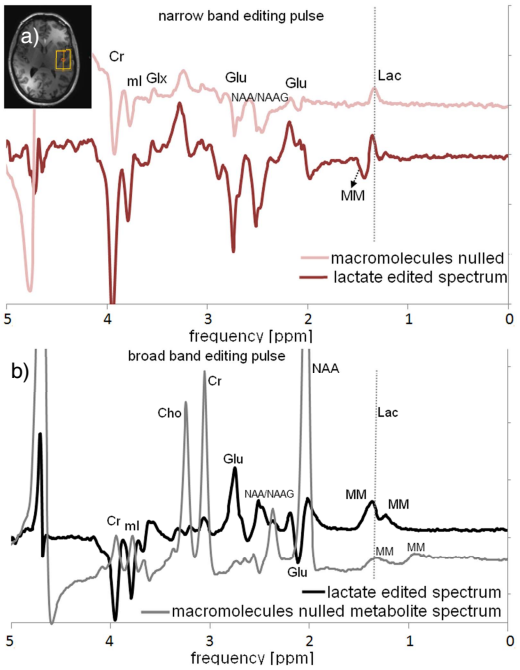

Figure 3: *Effect of co-editing of macromolecules on lactate signal. (voxel volume 36ml) Narrowband editing (a) and broadband editing (b).*