Towards a localized low power adiabatic 2D TOCSY for in-vivo use on clinical platforms

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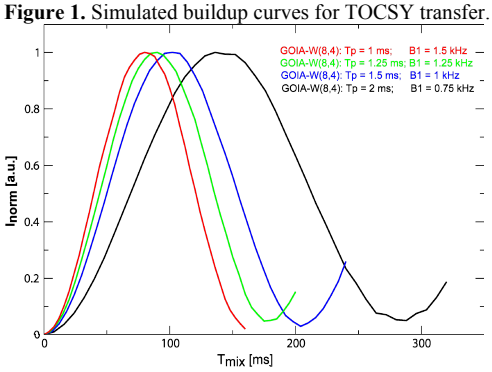
Abstract:
Two dimensional (2D) spectroscopy is very important for unambiguous assignment of overlapping metabolite signals. Although spectral simplification can be obtained through 1D spectral-editing techniques by filtering out some of the signals, the 2D spectra retain all the spectral information and could be more efficient in obtaining the complete metabolic profile. To date, 2D COSY (COrrelation SpectroscopY) and J-resolved spectroscopy have been demonstrated and applied to clinical questions. Here we present preliminary results towards a localized low power adiabatic 2D TOCSY (TOtal Correlation SpectroscopY) experiment on clinical platforms.

Introduction:
2D TOCSY [1] is one of the most powerful experiments in multidimensional NMR spectroscopy because it establishes the full connectivity in a spin network and due to its coherent magnetization transfer when compared to 2D COSY. However, the demands of a sustained rf field for spin-lock can be difficult to satisfy for in-vivo applications. 1D localized version of TOCSY (1D TOCSY-LASER) has been demonstrated recently in-vivo on research scanners [2], although to the best of our knowledge an in-vivo localized 2D TOCSY on clinical scanners has not been realized yet. We propose a modified version of the TOCSY-LASER including a z filter for mixing [3] and the use of gradient offset independent adiabaticity (GOIA) pulses [4,5] to reduce SAR deposition.

Methods:
All experiments have been performed on whole-body 3T Tim Trio clinical scanners (Siemens, Erlangen, software version VB17A), using body coil for transmit and the 32 channel head coil for receive. A phantom containing Lactate and Glutamate in equimolar concentrations (130 mM) has been used for demonstration. The TOCSY module consisted of an adiabatic MLEV-16 sequence and was followed by LASER localization using GOIA-W(8,4) pulses with T_p = 3ms, BW = 7 kHz, B_{1max} = 0.5 kHz. Typical parameters were: TR = 2s, TE = 30 ms (LASER), T_{mixing} = 64 ms (MLEV-16), NA = 8, 64 t1 increments, voxel size 25x25x25 mm.

Results:
Prior to the measurements, simulations where employed to predict the magnetization transfer of the mixing scheme under several experimental conditions. Numerical analysis presented in Figure 1 has been performed in GAMMA [6] for a two spin system (Lactate) considering the Hamiltonians for chemical shift, scalar coupling and the adiabatic rf field. For rf pulses that are shorter than 1.5 ms (B_{1max} higher than 1 kHz) the buildup curves are close to the optimum transfer curve with the maximum at 72 ms (1/2J) for Lactate. However, 1 kHz delivered with the body coil in-vivo can lead to a high SAR, and typically the transmit voltage is limited to obtaining a maximum B_1 value of 1 kHz. Hence, it is of interest to investigate the conditions that require lower rf power mixing. It can be seen that the buildups become gradually slower, and for an adiabatic pulse of 2 ms and B_{1max} = 0.75 kHz, close to 50 % of the total magnetization transfer can be obtained for mixing times in the range of 60 ms.

Figure 1. Simulated buildup curves for TOCSY transfer.



First, the localized 1D selective TOCSY-LASER experiment has been performed for the low power condition to test the transfer from the CH3 to CH group in the Lactate spin system. The spectra with no TOCSY (left, 0 ms) and TOCSY mixing (right, 64 ms) are shown in Figure 2. Following, a localized 2D TOCSY-LASER has been performed on the same phantom, and both spin systems of Lactate and Glutamate can be identified (Figure 3) in contrast with the spectral edited version of the 1D experiment. The SAR has been at 50 % from the maximum allowed value for the combined TOCSY (64 ms) and LASER (30 ms) contributions, using TR = 2s.

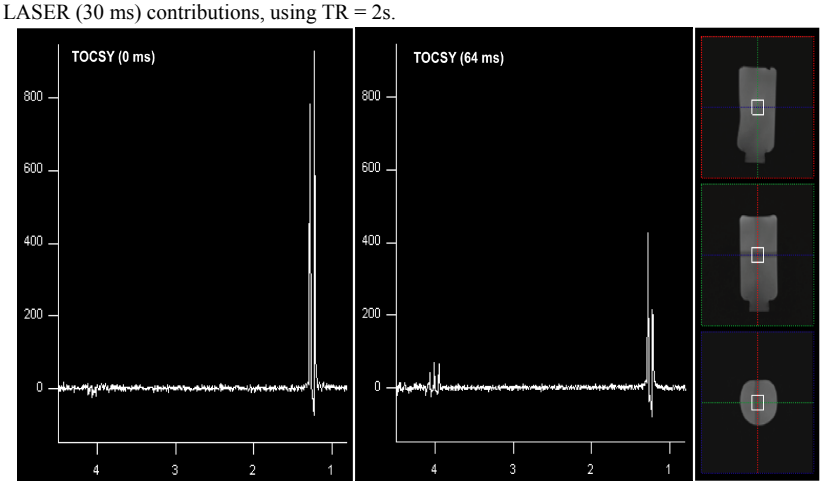


Figure 2. Lactate spectral editing using the 1D selective localized TOCSY-LASER.

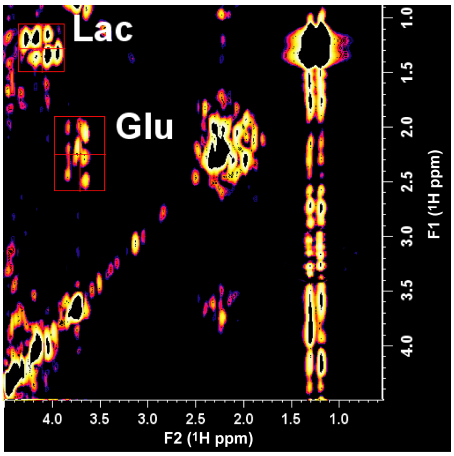


Figure 3. 2D localized TOCSY-LASER of the Lactate + Glutamate phantom

Discussions:
Our preliminary results indicate that 2D TOCSY-LASER under conservative low power requirements can be achieved on clinical scanners. It is expected that the important advantages of 2D TOCSY from analytical NMR spectroscopy can be mirrored for in-vivo human applications. Improvement of the 2D experiment and validations on volunteers and patients are planned next.

References:
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