Adiabatic Spiral Correlation Chemical Shift Imaging

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Introduction

The overlap of spectra in magnetic resonance spectroscopy limits the unambiguous identification and quantification of metabolites. Two of the most employed approaches involve fitting with a known basis set [1] and spectral editing [2]. Alternatively, multidimensional correlation spectroscopy [3] does not need to assume a certain basis set, nor needs to filter-out metabolites as in spectral editing. Here we present novel pulses sequences for correlation chemical shift imaging (CCSI) that use adiabatic excitation and spiral encoding to acquire the four dimensional (k_x,k_y,t_1,t_2) space.

Methods

All experiments were demonstrated on whole-body 3T Tim Trio clinical scanners (Siemens, Erlangen, Germany), using body coil for transmit and the 32-channel head coil for receive. We designed new pulse sequences for multivoxel two-dimensional (2D) Correlation Spectroscopy (COSY) and Total Correlation Spectroscopy (TOCSY) shown in Figure 1.

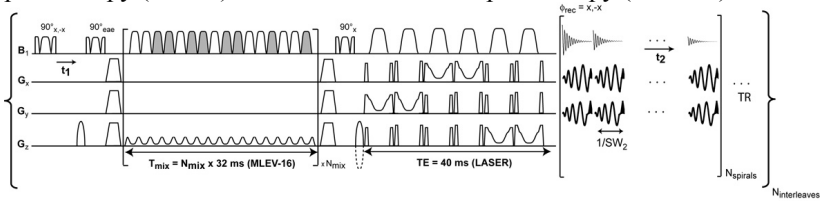

Figure 1. CCSI with Z-TOCSY-LASER-SPIRAL sequence.

Volume of interest is localized with LASER based on low power gradient modulated constant adiabaticity pulses [4]. Spatial encoding is realized with constant density spiral readout gradients [5]. TOCSY longitudinal mixing is obtained with a z-filtered MLEV-16 scheme employing gradient modulated constant adiabaticity pulses in order to reduce the SAR [6]. COSY can be easily obtained by removing the MLEV-16 block and z-filter from Figure 1.

Results

CCSI measurements were performed on a brain phantom, volunteers and patients with brain tumors. A single slice (2.5 cm thickness) with a matrix of 8x8 voxels (each 10 ml) of COSY and TOCSY spectra can be acquired in 8:32 min (TR = 1s) and 17:04 min (TR = 2s), respectively. TOCSY spectra have lower SNR than COSY, but contain additional crosspeaks for long range correlations over multiple-bonds and have better spectral resolution due to coherent in-phase magnetization transfer between coupled spins.

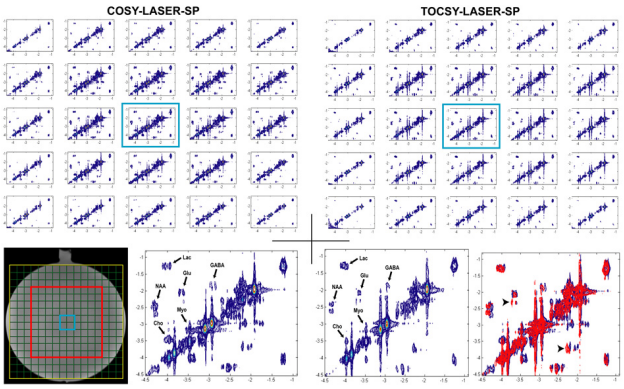

Figure 2. CCSI COSY and TOCSY of brain phantom. Overlay between the TOCSY (red) and COSY (blue) spectra in the lower right corner shows long range correlations and better resolution for TOCSY.

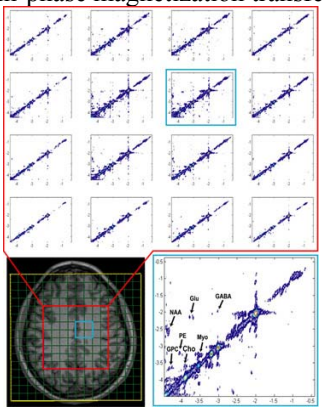

Figure 3. CCSI COSY of volunteer brain. A zoomed central voxel is shown.

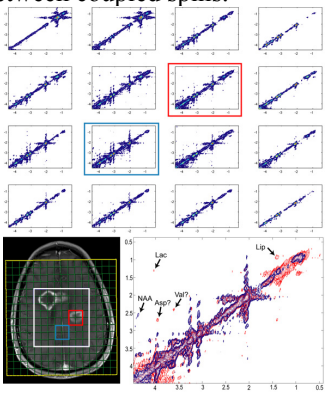

Figure 4. CCSI COSY of brain tumor patient. Lower right corner, overlay of tumor (red) and healthy (blue) COSY.

Conclusions

CCSI can be performed in a clinically feasible amount of time on human subjects and is able to resolve metabolites that are otherwise obscured in 1D MRS, such as GABA, the components of the total choline peak, or the overlap of lipids and lactate in tumors. Adiabatic excitation is optimal for coupled spins while spiral encoding is efficient for the simultaneous acquisition of two spatial (k_x,k_y) dimensions and the t_2 time dimension. These features may represent improvements over the EP-COSI method [7]. TOCSY imaging is demonstrated for the first time. CCSI has increased spectral dispersion compared to the 2D J-resolved imaging [8].

References: [1] Provencher S., MRM, 1993, 30(6):672-679; [2] Marjanska M. et al, MRM, 2005, 53(4):783-789; [3] Thomas M.A. et al, MRM, 2001, 46(1):58-67; [4] Andronesi O.C. et al, JMR, 2010, 203(2):283-293; [5] Adalsteinsson E. et al, MRM, 1998, 39(6):889-898; [6] Andronesi O.C. et al, MRM, 2010, DOI: 10.1002/mrm.22535; [7] Lipnick S. et al, MRM, 64(4):947-956; [8] Adalsteinsson E. et al, MRM, 1999;41(1):8-12.