Turbo Spin Echo Based Spatially Resolved Correlated Spectroscopic Imaging

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Introduction: Multi-Echo based acquisition schemes hold the promise of greatly reduced scan times in MR Spectroscopic Imaging (MRSI) (1-3). The one-dimensional (1D) spectrum extracted from the MRSI data has severe overlap of metabolite resonances due to J-interactions and co-resonant chemicals. Due to the added second dimension, two-dimensional (2D) MR Spectroscopy (MRS) offers better spectral dispersion and enables better identification of several J-coupled metabolites (4-5). 2D MRS combined with conventional spatial encoding schemes can be extremely time consuming; for e.g., a single-echo acquired MRSI combined 2D COSY sequence can take two or more hours. Hence, faster 2D spatial encoding schemes need to be added to the required second spectral encoding in 2D MRS (1-3). Multi-echo based acquisition can reduce the total duration by a factor of four or more. The purpose of this study is to demonstrate the feasibility of a 4-echo based 2D COSY sequence on a whole body 3T MRI scanner.

Methods: A four-echo-based spatial encoding scheme has been integrated into 2D L-COSY sequence containing three slice-selective radio-frequency (RF) pulses (90^0, 180^0, 90^0) on a Siemens 3T Trio-Tim MRI scanner currently running on the VB15 platform. This sequence uses a turbo-spin-echo (TSE) module after the last 90^0 slice-selective RF pulse, named as Turbo Spin Echo based Correlated Spectroscopic Imaging (TSE-COSI). After compiling the TSE-COSI sequence using the Siemens Idea VB15 compiler, a 100 mM lactate phantom was investigated using a circularly polarized (CP) extremity transmit/receive coil. A 26 year old healthy volunteer was also investigated to record the multi-voxel based COSY spectra in calf muscle. The following parameters were used: TR = 2 sec, TE = 30 ms, NEX = 1, 8x8 2D spatial encoding (the spatial encoding gradients along one dimension was distributed before and after the refocusing 180^0 pulse in the TSE echo-train), 4000 Hz bandwidth, 64 $\Delta t1$ of 1 ms increments before the 90º pulse were used in the lactate phantom. Only 50 $\Delta t1$ increments were used in the calf muscle. Minimal voxel size for the lactate phantom was 8 ml and 6 ml in the calf muscle. Total scan time was 34 minutes and 27 minutes for the lactate phantom and calf muscle scans, respectively.

Results: Shown in Figure 1 is the extracted COSY spectra from the four central k-space voxels of a 100 mM lactate phantom. The diagonal and cross-peaks of lactate were identified at (F1 = 1.2 ppm, F2 = 4.1 ppm). The volume of the extracted voxel in the lactate scan was 8 ml. The calf muscle data shown in Figure 2 displays clearly the cross-peaks from the intra-myocellular lipid (IMCL) and extra-myocellular lipid (EMCL) at their expected locations (2) numbered 6 and 7 (6). In the calf muscle, the volume of the extracted voxel was 6 ml. As expected, data outside of central K-space showed greatly reduced signal.

Figure 1: Central four voxels from the 100 mM lactate phantom showing lactate cross peaks (1,2), diagonal peak (3) and unsuppressed water (4)

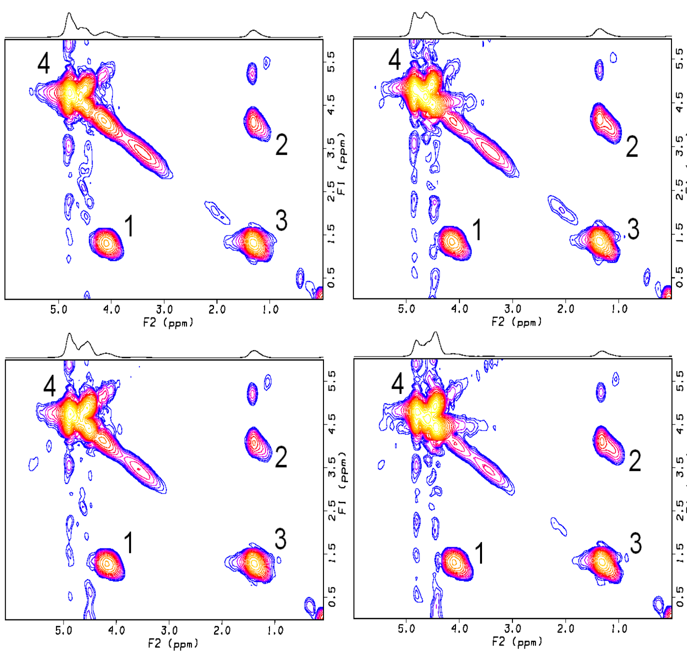
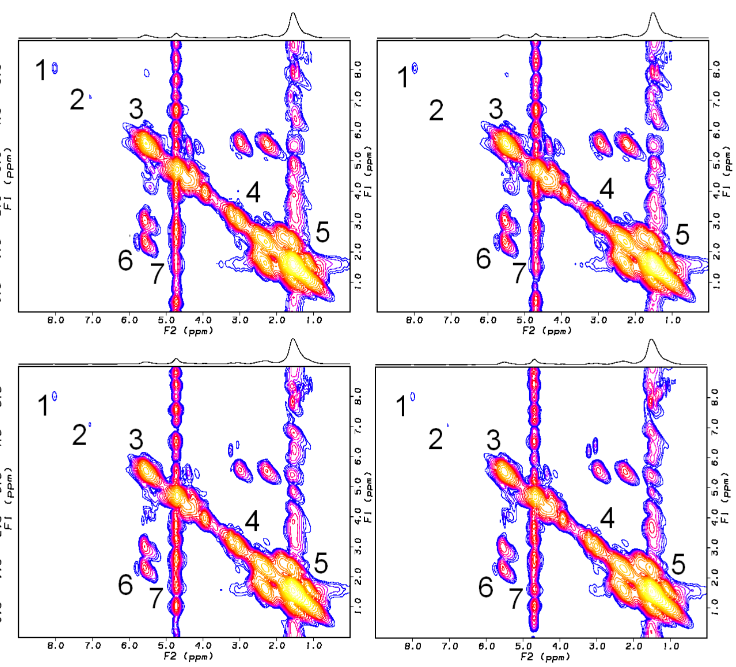


Figure 2: Central four voxels from calf muscle showing carnosine diagonal peaks (1,2), olefinic protons (3), creatine (4), fat (5), EMCL (6) and ICML (7)



Conclusion: We are able to observe viable 2D MRS data in both the 100 mM lactate phantom and *in vivo* calf muscle. Total scan time for the calf muscle (TE = 30 ms, TR = 2 sec, 8-by-8 spatial resolution, 50 measurements) was 27 minutes, reduced from almost 2 hours for a single-echo based scan. Acquiring four echoes in a single TR introduces the element of T2 losses in the multi-dimensional data. The earlier echoes in each TR should be acquired from the central K-space, whereas the later echoes could be acquired from areas outside the volume of interest. Because the data is not acquired from consecutive voxels in the K-space, it must be re-ordered according to the acquisition scheme. Longer echo train lengths allow for the possibility of further reducing scan times, analogous to multi-echo schemes in MRI such as TSE. These pilot findings demonstrate the feasibility of implementing a TSE-based COSY and analogous versions of 2D MRS can be developed.

References:

1. Duyn JH and Moonen CT. *Magn Reson Med* 1995;33:101.
2. Herigault G, Zoula S, Remy C, et al. *MAGMA* 2004;17:140
3. Dydak U, Meier D, Lamerichs R and Boesiger P. *AJNR Am J Neu*roradiol 2006;27:1441
4. Thomas MA, Yue K, Binesh N et al. *Magn. Reson. Med.* 2001; **46:** 58-67
5. Schulte, RF and Boesiger P. *NMR Biomed* 2006; **19**: 225-263
6. Velan SS, Durst C, Lemieux S, Raylman RR, Sridhar R, Spencer RG, Hobbs GR, Thomas MA. *JMRI* 2007; 25:192-199