Fast CT-PRESS Based Spiral CSI at 3 T

D. Mayer[1], D-H. Kim[1], E. Adalsteinsson[1], D. M. Spielman[1]
[1]Radiology, Stanford University, Stanford, CA, United States

Introduction

Even at a field strength of 3 T the detection of signals from scalar coupled metabolites, e.g., glutamate (Glu) and *myo*-inositol (mI), in MR chemical shift imaging (CSI) is often hampered by spectral overlap due to the small dispersion of the chemical shift (CS) and line splitting caused by J-coupling. The spectral resolution can be increased by combining CSI with two-dimensional (2D) correlation spectroscopy (COSY) [1,2] or 2D-J resolved spectroscopy [3]. But this is at the expense of the minimum total measurement time. Constant Time PRESS (CT-PRESS) [4] has been introduced as a single voxel technique to detect coupled resonances with effective homonuclear decoupling and high signal-to-noise ratio (SNR). As usually fewer CS encoding steps are necessary in CT-PRESS compared to COSY based techniques, the aim of this work was to combine CT-PRESS with fast spiral CSI [5] as an alternative to short TE CSI.

Methods

All measurements were performed on a GE 3 T MR scanner equipment with self-shielded gradients (40 mT/m, 150 mT/m/ms). A quadrature bird-cage coil was used for both RF excitation and signal reception.

The implemented sequence consists of five parts: (a) three CHESS pulses for water suppression, (b) an outer volume suppression module, (c) a PRESS module (TE/TR = 30/2000 ms) for slice(*z*)- and in-plane pre-selection, (d) an additional refocusing pulse for CS encoding in f_1, and (e) a spiral readout gradient for combined spatial(*xy*)-spectral(f_2) encoding. The CS encoding pulse was shifted in increments of 6.4 ms in 17 steps leading to a spectral width SW_1 of only 78.125 Hz. Therefore, the 2D spectra are severely aliased in f_1. But as the signals occur close to the spectral diagonal in CT-PRESS the aliasing does not lead to signal overlap. The evolution time t_c (echo time at the central CS encoding step) was 151 ms. All refocusing pulses had flip angles of 167°. Due to hardware restrictions the number of data points acquired continuously at the readout bandwidth of 250 kHz was 7168. Therefore, each readout consisted of n_{cat} blocks of 7168 points to increase the nominal spectral resolution in f_2. The readout was repeated with the start of data acquisition shifted by 1.3 ms to fill the resulting gaps in the acquisition. Two spiral designs were tested: (a) 4 spatial interleaves with a FOV of 24×24 cm^2 for a 16×16 matrix and SW_2 of 1196 Hz (n_{cat} = 9, T_{meas} = 4:40 min), and (b) 12 spatial interleaves with an oversized FOV of 48×48 cm^2 for a 32×32 matrix and SW_2 of 1050 Hz (n_{cat} = 10, T_{meas} = 13:44 min). The spiral CSI module was shifted together with the CS encoding pulse in order to increase the SNR.

The data post-processing comprised gridding, apodization in the spectral dimensions (multiplication with sine-bell functions and zero-filling), and FFT. A t_1-dependent linear phase correction was performed along f_2 to correct for the differences of the start of data acquisition. After unwrapping the 2D spectra in f_1 diagonal spectra were calculated by integrating the signal along f_2 within a ±13 Hz interval around the spectral diagonal.

Results and Discussion

The sequence was tested on a spherical GE MRS phantom filled with a solution of various brain metabolites at physiological concentration levels. The 2D contour plot from a single voxel of the phantom (Fig. 1, bottom) demonstrates the effect of the effective decoupling scheme as the line splitting due to J-coupling is suppressed in f_1. Therefore, all the signals appear as single lines in the corresponding diagonal spectrum (Fig. 1, top). Note the additional N-acetyl aspartate (NAA) resonance at 2.58 ppm which is due to strong coupling effects between the C2 and C2' protons. For the in vivo application of the method a 20×92×108 mm^3 volume (axial slice orientation) was selected above the ventricles of a healthy volunteer. Both the 2D contour plot and the corresponding diagonal spectrum from a voxel containing predominantly gray matter (Fig. 2) show the good separation of the Glu C4 resonance at 2.35 ppm. Additionally, signals from NAA, total creatine (tCr), choline containing compounds (Cho) and mI could be detected. Figure 3 shows a spatial map of diagonal spectra (4 ppm ≥ f ≥ 1 ppm). All voxels are completely within the volume selected by the PRESS module.

Conclusion

The presented data show the feasibility of combining CT-PRESS with a fast spiral based CSI technique. This allows the acquisition of multi-voxel spectroscopic data without line splitting. By using effective decoupling this work demonstrates that compounds such as Glu and mI can be reliably measured without water or lipid baseline artifacts which typically hamper short TE CSI. With the short minimum measurement time it is possible to extend the sequence to obtain 3D spatial information within acceptable scan times by applying Hadamard encoding in the slice direction. A sequential multi-slice version is possible by making the CS encoding pulse slice-selective.

References

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Acknowledgement

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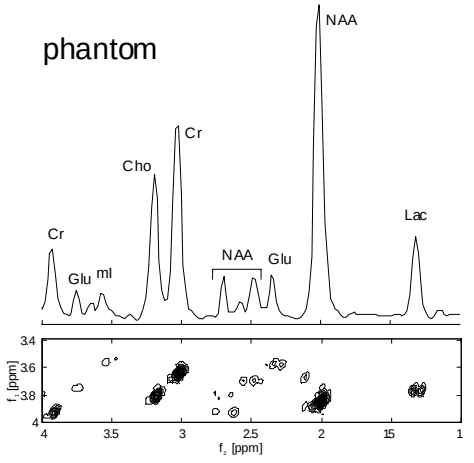

Fig. 1: 2D contour plot and diagonal spectrum from a single voxel from a phantom filled with a solution containing various metabolites (T_{meas} = 4:40 min, 2×1.5×1.5 cm^3 nominal voxel size).

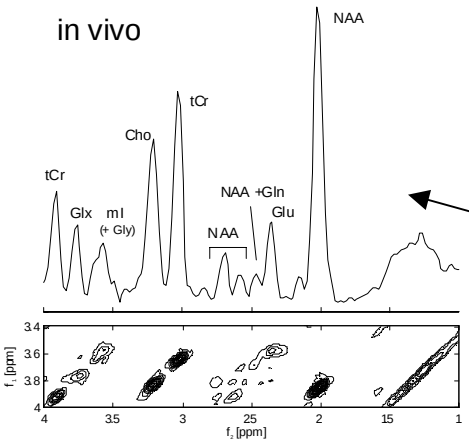

Fig. 2: 2D contour plot and diagonal spectrum from a single voxel containing mainly gray matter from a healthy volunteer (T_{meas} = 13:44 min, 2×1.5×1.5 cm^3 nominal voxel size).

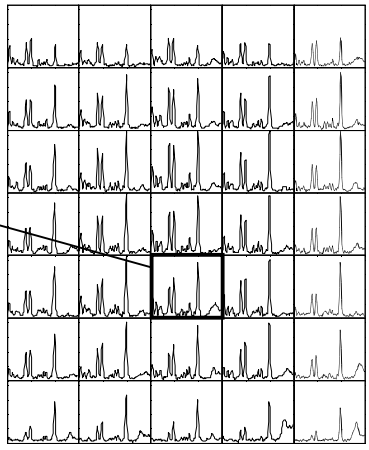

Fig. 3: Map of diagonal spectra (4 ppm ≥ f ≥ 1 ppm). All voxels are completely within the volume selected by the PRESS module.