Phase-sensitive Localized COSY (PS-LCOSY)

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INTRODUCTION

Two-dimensional (2D) localized correlation spectroscopy (L-COSY) uses three slice-selective radio-frequency pulses (90^0ss-180^0ss-90^0ss) for volume of interest (VOI) localization with the last RF pulse used for coherence transfer and spatial localization (1). Pilot evaluations in healthy human subjects and selected pathologies have shown interesting findings due to the improved spectral resolution facilitated by the added dimension (2,3). One of the drawbacks of L-COSY is that the 2D spectra are presented in the magnitude mode resulting in twisted line shapes leading to inability in resolving the cross peaks close to the diagonal of the 2D spectrum. It has been demonstrated in high resolution NMR that phase-sensitive (PS) LCOSY minimizes the twisted line shapes and enhances resolution in the direct (F_2) and indirect (F_1) dimensions when compared to its magnitude counterpart (4). We present here our preliminary results from a novel implementation of localized phase-sensitive homonuclear correlated spectroscopy (PS-LCOSY) using a whole body MRI scanner.

MATERIALS AND METHODS

2D MRS data was collected on a standard 3T Magnetom Trio system (Siemens AG, Erlangen, Germany) equipped with a 60 cm diameter bore (software version VA25A) and a CP head coil (Siemens AG, Erlangen, Germany). A brain MRS phantom containing standard brain metabolites at physiological concentrations and 1 ml/l Gd-DPTA (Magnevist) was used. The implemented pulse sequence used for PS-LCOSY is shown in Figure 1. The VOI was localized using the first three RF pulses (90^0ss-180^0ss-180^0ss) and the coherence transfer for COSY was enabled by a hard 90^0 RF pulse surrounded by B_0-crusher gradient pulses. The phases of the RF pulses are as reported in (5), while the phase of the terminal 90^o alternated between 0 and 180 to cancel the frequency induction decay (fid) produced by the last RF pulse. The RF carrier frequency was set at 2.4 ppm and the following parameters were used for the acquisition of 2D MRS: TR 2 s, TEmin=30 ms, VOI size of 3x3x3 cm3, global water suppression using WET (6), spectral width=2000 Hz along t_2, 64 increments (Δt_1) for the second spectral dimension with Δt_1 of 0.6 ms giving an indirect spectral width of 1666 Hz, 4 averages per Δt_1, and 1024 data points. The N- and P-type COSY were acquired when G1=G2 and G1= -G2, respectively.

Two different post-processing methods were developed: 1) The N-type and P-type time domain matrices were combined in Matlab in a way where the rows from the two experiments alternated in the final phase sensitive matrix. This means that the matrix size doubled along the F_1 dimension. Further processing was done with MestReNova program (7). Fourier transform was applied in the quadrature mode along F_2, while quadrature/echo-antiecho processing mode was used along F_1 to preserve phase information. 2) Without using the acquired P-type COSY spectral data, a synthetic P-type spectrum was obtained directly from the acquired N-type by reversing the raw data matrix along F_2. The rows of this 'synthetic' P-type data matrix were then interleaved to produce a new 2D matrix, which was then post-processed the same as described above.

RESULTS AND DISCUSSION

Figure 2 shows 2D PS-LCOSY spectra reconstructed through the above mentioned schemes combining: A) acquired N-type and P-type raw matrices and B) acquired N-type and synthetic P-type data. Phase sensitive horizontal traces are shown above for each method for comparison. Anti-phase cross peak and in-phase diagonal peaks are obvious in both cases, in accordance with expected theory (4).

Generation of phase sensitive COSY spectra is well described in high resolution NMR by using RF phase based methods such as time proportional phase incrementation "TPPI" (8*)* and States-Haberkorn Reuben "SHR" methods (9). These methods, however, are less suitable to gradient assisted techniques. Echo-antiecho technique (7), in which a negative (N-type) and positive (P-type) signals are acquired and interleaved before processing, are more suitable. However, this has not been implemented in the localized 2D MRS. The raw data of spectrum shown in Figure 2B was fully acquired, whereas half of the raw data of the spectrum shown in Figure 2A was acquired (N-type signal) and the other half was synthesized as described above. The effect of horizontal reversal of data can be surprising, but in reality, it is a manifestation of the "time shift" feature of Fourier transform theory. One advantage of PS-LCOSY is detecting cross peaks with small J value and low intensity. These cross peaks might cancel out in a magnitude mode processing. The overall signal to noise ratio is also improved by a factor of $\sqrt{2}$ while at the same time improving resolution (4).

CONCLUSION

PS-LCOSY can be acquired on a whole body scanner by using the echo-antiecho technique. Enhancement of resolution can be obtained along both dimensions. A new technique by which half of the data is 'synthesized' from acquired data can be used to produce PS-LCOSY, thus minimizing the total acquisition time.

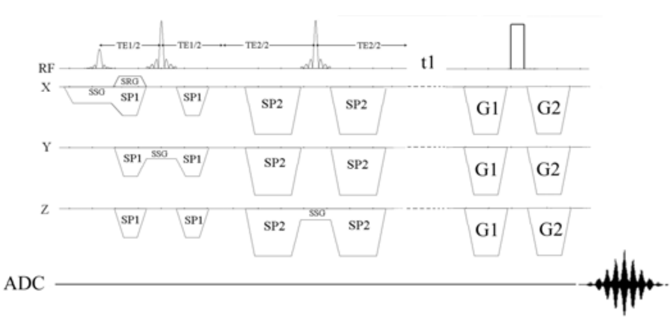

Figure1. Pulse sequence used in PS-LCOSY. Note that N-type (echo) and P-type (antiecho) signals are acquired in an interleaved mode. N-type signal is acquired when G1=G2, while P-type signal is acquired when G1= -G2. RF flip angles are 90^0-180^0 -180^0 -90^0,. Abbreviations are : SSG-slice selection gradient, SRG-slice refocussing gradient, SP1 and SP2 are first and second spoilers/crushers. G1 and G2 are coherence selective and spoiler gradients

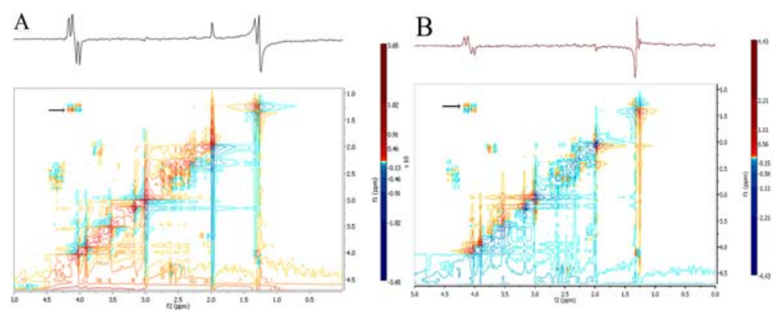

Figure2. PS-LCOSY spectrum of brain phantom acquired on a 3T scanner using a CP head coil. The raw data of the left spectrum (A) was made by synthesizing P-type from the acquired N-type raw data. The raw data of the right spectrum (B) was made by acquiring P-type and N-type raw data. Acquisition and processing parameters are as described in text.

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