Adiabatic L-COSY at 7T

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INTRODUCTION

In vivo Localized Correlation Spectroscopy (L-COSY, 90ss 180ss t1 90ss Acq) [1] is a developing technique that enables researchers to un-scramble spectroscopic findings in a relatively narrow spectral bandwidth along a second dimension, and thus, facilitating analysis and improving reliability. However, using this technique at high Bo fields [2] requires appropriate optimization. Namely, the following issues must be addressed: (1) lower available peak RF amplitude, (2) easily reaching a high SAR level (3) higher B1 inhomogeneity due to dielectric resonances and long RF wavelength and (4) requirement of larger excitation and refocusing pulses bandwidths to reduce chemical shift misregistration, Δx, where it can be quantified as $\Delta x = \Delta\omega/\gamma G$, where $\Delta\omega$ is resonance frequency difference between any 2 spectral lines, γ is the gyromagnetic ratio and G is the amplitude of slice selective gradient. Inhomogeneous B1 fields at 7T means that Shinnar-Le Roux optimized refocusing pulses cannot be used, let alone the associated SAR levels. We here present the first application of adiabatic-Localized-COSY (AL-COSY) where spatial selection and excitation along two orientations is achieved by two pairs of slice-selective adiabatic inversion pulses, thereby increasing bandwidth and reducing B1 sensitivity [3].

MATERIALS AND METHODS

This technique was developed on a 7T MR scanner (Siemens Medical Solutions, Erlangen, Germany) with a 28 cm diameter de-tunable birdcage coil for excitation and reception. Localizer images were obtained using a gradient-echo imaging sequence.

The pulse sequence used in this work is shown in Figure 1. A non-spatially-selective adiabatic RF pulse globally excites the tissue. Two pairs of HS1 pulses spatially refocus the magnetization along two planes. Magnetic gradient spoilers were inserted before and after each HS1 pulse to ensure spoiling of unwanted signal. Δt1 followed to allow single quantum evolution, followed by a slice selective sinc pulse to allow for spatial selection and coherence transfer. A short delay was allowed after terminal spoiler to dissipate eddy currents, after which signal was acquired.

Amplitude and frequency modulations of adiabatic hyperbolic secant pulse used in this work were described in detail elsewhere [3]. Briefly, amplitude and frequency variable functions were $f_B(t)= \mathrm{sech}\,[\beta\,((2t/T)-1]$ and $f_W(t)= \tanh\,[\beta\,(1-(2t/T))]$, respectively, where T is pulse duration of 5120 us, $0<t<T$, and 1% cutoff level (i.e. $\mathrm{sech}(\beta)=0.01$). A bandwidth-time product (R) value of 30 was used, which produced an RF refocusing bandwidth of 5.9 KHz.

A brain MRS phantom containing standard brain metabolites at physiological concentrations and 1 ml/l Gd-DPTA (Magnevist) was used. Experimental parameters are: RF carrier frequency set to 2 ppm, TR=2 s, TE_{ini} 42ms (initial delay from first 90^o RF to terminal 90^o RF), voxel size: 2x2x2 cm^3, water suppression was achieved with WET [4], spectral width=4000 Hz along t_2, 64 increments (Δt_1) for the second spectral dimension with Δt_1 of 0.25 ms giving an indirect spectral width of 4000 Hz, and 8 averages per increment, and 2048 complex data points were acquired. Data from L-COSY [1] pulse sequence was also collected using the same above acquisition parameters.

Further processing was done with Felix program [5]. Fourier transform was done after zero filling to double the acquired matrix size in both dimensions, and multiplying F2 and F1 by skewed sine^2 and sine^2 apodization functions, respectively. Peak volume evaluation was done using standard Felix software features, and all values were normalized for comparison. Note that data from L-COSY and AL-COST were processed in the same manner.

RESULTS AND DISCUSSION

After processing data acquired with both pulse sequences equally, the lower and upper ranges of cross peak volume improvement was 47% to 127%, when L-COSY data is compared to AL-COSY. A higher cross peak volume is desired as this is used for quantitation with programs like ProFit [6].

Slice profile obtained with HS1 pulse was sharper and more defined when compared to profile obtained with Mao pulse (Data no shown).

Standard optimized Mao pulse [7] with a duration 6ms and a refocusing bandwidth of 997Hz at 7T, will yield a chemical shift artifact of 112% over 3.8 ppm range. The proposed pulse sequence with the HS1 pulses will reduce the chemical shift artifact to 20%. The SAR level obtained with AL-COSY pulse sequence was acceptable (70% of maximum SAR scale) and much lower that obtained with other adiabatic pulses. Thus, it poses no risk to patients. At shorter TR or with different types of adiabatic pulses with much larger bandwidth, SAR level might pose a challenge. In this case, a transmit-receive surface coil will probably reduce SAR levels and enhance overall SNR. The later setup is being evaluated. Inhomogeneity of surface coil profile can be reduced by using adiabatic pulses. Further reduction in SAR and chemical shift artifact can be obtained by a combination of adiabatic RF pulses and variable amplitude gradient pulses [8,9].

Signal loss due T2 relaxation is expected to be minimal at a starting TE_{ini} of 42 ms due to the fact that relaxation during this period is governed by T2 within the rotating frame, which is longer than T2 and T2*[3].

CONCLUSION

The proposed technique is, to our knowledge, the first implementation of AL-COSY. Preliminary results show that cross peak volumes can be improved with AL-COSY. SAR values were below FDA guidelines all the time. In vivo evaluations of AL-COSY will follow.

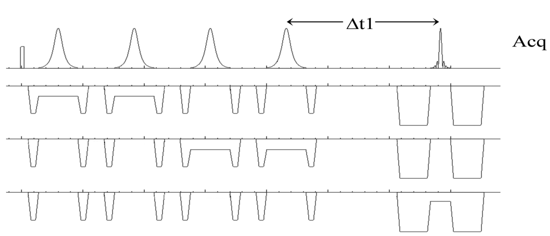

Figure1. AL-COSY sequence starts with a non-localized adiabatic 90^o RF pulse, followed with one pair of HS1 RF pulses in one direction and another pair of HS1 pulse in another direction. One pair of HS1 RF pulses are needed along each direction since a single adiabatic pulse does not achieve acceptable rephasing of transverse magnetization. The terminal pulse is a sinc pulse and acts as a slice-selection pulse and as a coherence transfer pulse simultaneously.

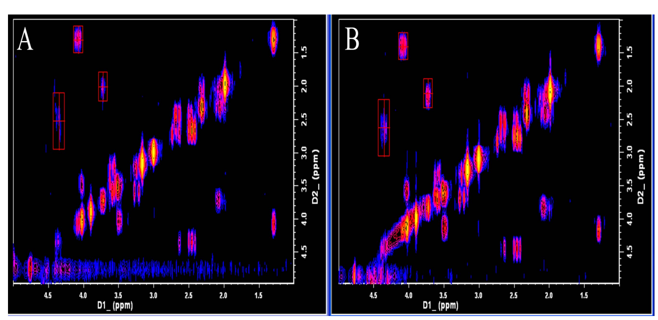

Figure2. L-COSY spectrum (A) and AL-COSY spectrum (B) showing the improvement in cross peak amplitude in red boxes.

References

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