# Symmetric Echo Acquisition of Hyperpolarized C-13 MRSI Data in the TRAMP Mouse at 3T

**A. P. Chen[1], R. E. Hurd[2], C. M. Cunningham[3], M. Albers[1,4], M. L. Zierhut[1,4], Y-F. Yen[2], J. Tropp[2], R. Bok[1], S. J. Nelson[1,4], J. Kurhanewicz[1,4], and D. B. Vigneron[1,4]**

[1]Radiology, UCSF, San Francisco, CA, United States, [2]GE Healthcare, Menlo Park, CA, United States, [3]Sunnybrook Health Sciences Centre and Dept. of Medical Biophysics, University of Toronto, Toronto, Ontario, Canada, [4]Joint Bioengineering Group, UCSF/UCB, San Francisco, CA, United States

**Introduction:** Almost all proton or non-proton MRSI data acquisitions acquire only the right hand side of the spin-echo due to desired spectral resolution that results in long readout duration and limited T2 relaxation time. Acquiring the full spin-echo for MRSI can theoretically improve SNR and eliminate the imaginary component thus allow the magnitude spectra to be displayed with the same line shape as the pure absorptive component of the spectra. Hyperpolarized $^{13}C_1$ pyruvate via dynamic nuclear polarization (DNP) has been shown to allow acquisition of high resolution MRSI data when it is injected into normal rats (1) and transgenic adenocarcinoma of mouse prostate (TRAMP) mice (2). The T2 relaxation time (3) of the hyperpolarized substrate may allow the use of a longer echo time (TE) without significant reduction in SNR. In addition, the large spectral separations of the $^{13}C$ metabolites reduced the spectral resolution required thus shortened the sampling duration. This goal of this study is to determine the feasibility and potential improvement in SNR of acquiring full spin-echo $^{13}C$ MRSI data using a double spin-echo pulse sequence.

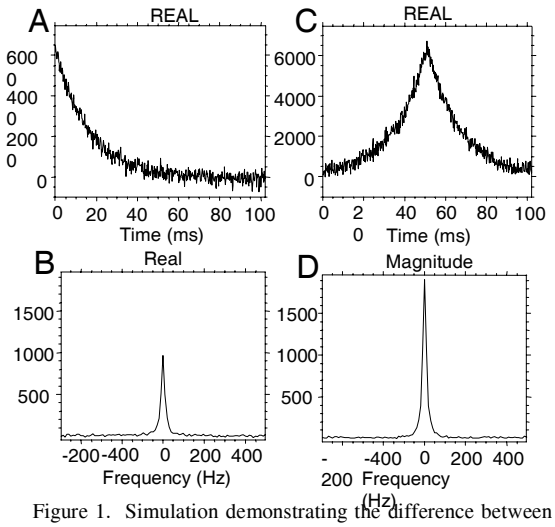


Figure 1. Simulation demonstrating the difference between MR spectroscopy data acquired from just right hand side of the spin-echo (A-B) and both side of the spin-echo symmetrically (C-D). The simulated data have the same readout duration, noise and T2* (A and C). Note the same line shape between the pure absorptive spectra from the half echo (B) and the magnitude spectra from the symmetric echo (D). Also note the two fold higher signal amplitude for the symmetric echo spectra compared to the half echo spectra.

**Methods:** *Simulation:* Simulations were performed using SAGE™ software. Two time-domain simulated data sets were created to represent a single resonance MR data when only the right hand side of the echo is acquired as well as when the full spin-echo is acquired symmetrically (Figure 1A and 1C). Both data sets have the same readout duration (100 ms), noise (5% st.dev.) as well as T2* relaxation time (100/2π ms, or 10 Hz FWHM). *In vivo experiment:* All studies were performed using a GE 3T scanner (GE Healthcare, Waukesha, WI) using a custom build dual-tuned quadrature $^{13}C/^{1}H$ mouse coil. A double spin-echo pulse sequence with small tip-angle excitation, adiabatic refocusing and flyback echo-planar readout trajectory was used to acquire *in vivo* 3D hyperpolarized $^{13}C$ MRSI data from TRAMP mouse after the animal was injected with hyperpolarized $^{13}C_1$ pyruvate (1-2). 3D MRSI data were acquired with an 8x8x16 matrix and a 40mmx40mmx86.4mm FOV (0.135cc resolution). TR/ TE was 160/35 ms when the right hand side of the echo was acquired and 215/140 ms when the full spin-echo was acquired; the readout duration (101.48ms) and readout trajectory were the same for both acquisitions. The flyback trajectory was designed for 581Hz bandwidth and has 59 readout/rewind lobes (9.83 Hz/pt spectral resolution); with a 25000Hz/2538 readout filter, 16 k-space points were acquired in each TR. Total acquisition time was 10s for the half echo acquisition and 14s for the full echo acquisition.

**Results:** The simulated data showed that the symmetric full echo data has equivalent line shape in magnitude mode compare to half echo data in pure absorption mode (Figure 1B and 1D). The signal amplitude was approximately two fold higher for the full echo data compared to the half echo data. *In vivo* comparison using $^{13}C$ MRSI data from voxels in the TRAMP mice tumors using the half echo acquisition (Figure 2A) and full echo acquisition (Figure 2B) also demonstrated the similarity in line width between the real data from half echo and the magnitude data from full echo (13.6 Hz vs 14.2 Hz). The SNR from the mice tumor *in vivo* was higher for the full echo data (lactate SNR = 117) compared to the half echo data (lactate SNR = 71).

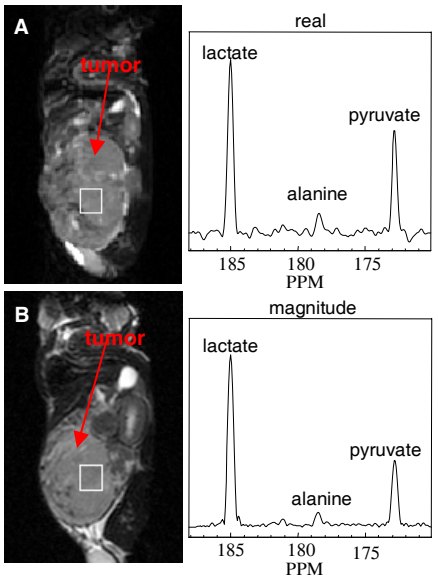


Figure 2. Hyperpolarized 13C MRSI data acquired from TRAMP mouse with both half echo (A) and symmetric full echo (B) acquisition. 3D MRSI data were acquired using a double spin-echo sequence with adiabatic refocusing and flyback echo-planar readout with a 8 x 8 x 16 matrix and 0.135cc nominal resolution. Sagittal T2-weighted FES images of the mice and spectra from the mouse prostate tumors are shown, demonstrating high lactate peak. Note the similar line shape between pure absorptive spectrum from half echo (13.6 Hz for lactate) and magnitude sptectrum from full echo (14.2 Hz for lactate). SNR was also higher for full echo data (1.6 fold higher for lactate).

**Discussions:** One of the properties of hyperpolarized $^{13}C$ spins (long T2) and the large chemical shift dispersion of $^{13}C$ spectrum allows the acquisition of full echo MRSI data with a double spin-echo pulse sequence. The equivalent line shape between the magnitude spectra from full echo and the pure absorption spectra acquired from just the right hand side of the echo negate the need to apply phase correction to the MRSI data sets. The SNR improvement *in vivo* for the full echo acquisition was 65% higher than for the half echo data but less than what was demonstrated with simulation. The longer TE used for the full echo acquisition and the difference in tumor progression (difference in lactate production) have probably also contributed to this result.

**References:**

1. Golman, K. et al. Proc Natl Acad Sci U S A 2006; 103:11270-11275.
2. Chen AP. et al. Proc., ISMRM, 14th Annual Meeting. #587.
3. Svensson J. et al. Mag Res Med 2003; 50:256-262.