Spectroscopic Imaging of ^{1}H at 3T: Comparing SNR between Traditional Phase Encoding and Echo-Planar Techniques in the Human Brain

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INTRODUCTION:

Spectroscopic imaging can be used to non-invasively assess spatial distributions of metabolite concentrations. This is of particular importance in various disease assessments, specifically in the brain. However, by adding this additional dimension to images, acquisition time can be significantly increased. Using echo-planar techniques, it is possible to dramatically reduce spectroscopic image acquisition time and still achieve quality data. In addition, the field of view (FOV) in the echo-planar dimension can be increased without a cost in acquisition time. A larger FOV will prevent unwanted signal from aliasing into voxels of interest and corrupting the spectra. This is a particular problem for lesions near the vertex of the brain.

METHODS:

Echo-planar spectroscopic imaging (EPSI) makes use of alternating gradient echoes during data acquisition to simultaneously encode spectral and spatial information. Flyback EPSI plays a positive gradient echo for encoding followed by a rapid negative "flyback" gradient echo [1]. Only data acquired during the stable period (at the plateau) of the positive gradient echo are used in reconstruction. Similarly, symmetric EPSI uses an alternating encoding gradient; however, the negative gradient echo is identical in magnitude and opposite in direction to the positive gradient echo, and its data are thus used in reconstruction. Interleaving two data sets is also possible by acquiring one flyback data set and then time shifting the next identical acquisition by one-half the echo time.

In this study, 4 MR spectroscopic phantoms and 5 volunteers were examined to determine how the signal-to-noise ratios (SNR) of various spectroscopic imaging techniques compare. Specifically, traditional phase-encoded chemical shift imaging (CSI) (FOV=12cmx12cmx8cmx2kHz, res=1cm^{3}x1.95Hz, NEX=1, TA=21:12, TR=1100ms) was compared to multiple EPSI techniques, including: flyback (FOV=16cmx16cmx16cmx988Hz, res=1cm^{3}x1.39Hz, NEX=2, TA=9:32, TR=1109ms), interleaved flyback (FOV=16cmx16cmx16cmx1012Hz, res=1cm^{3}x1.17Hz, NEX=1, TA=10:10, TR=1173ms), and symmetric EPSI (FOV=16cmx16cmx12cmx977Hz, res=1cm^{3}x1.91Hz, NEX=2, TA=9:30, TR=1100ms). Symmetric EPSI data was also reconstructed at a higher spatial resolution (0.86cm^3) after incorporating additional data acquired during gradient transition (on the ramps). Echo-planar encoding was performed in the SI dimension in each EPSI sequence. Data were acquired on a GE Signa 3T scanner with an 8-channel phased array head coil. Each sequence used a chemical shift selective (CHESS) water suppression pulse and very selective saturation (VSS) pulses to prevent lipid contamination from the scalp. Also, in each sequence a point resolved spectroscopy (PRESS) box was prescribed with an 8cmx8cmx4cm selected volume. After acquisition, data were processed to remove any zero order and first order phase artifacts and to remove the residual water peak. Additional linear phase correction in frequency and k-space was also performed in the echo-planar dimension for EPSI sequences. Each symmetric EPSI reconstruction processed the positive and negative gradient lobe data points separately and also combined them after processing.

Because these techniques have varying acquisition times, a relative drop in SNR is accounted for in the faster acquisitions. The relative SNR ratio is calculated with respect to CSI SNR, according to the following equation:

$$Ratio_{rel_i} = \Delta V_i \sqrt{TA_i} \Big/ \Delta V_{CSI} \sqrt{TA_{CSI}} \qquad (1)$$

where ΔV_i is the voxel resolution and TA_i is the total acquisition time for the ith EPSI sequence. SNR was calculated using MATLAB. Noise values were taken as the standard deviation of a spectral region without metabolite signal within the prescribed PRESS box. Signal was measured as the median metabolite peak height within the PRESS box and in voxels containing at least 90% white matter, as determined from a hidden Markov random field model segmentation. All voxels within the PRESS box were used for SNR calculations in the phantoms. SNR ratios for the various acquisition techniques were calculated and the percent difference from the relative SNR ratio was compared for each metabolite in each exam.

RESULTS:

The median percent difference from the relative SNR ratio is shown in Table 1 for choline, creatine, and N-acetyl aspartate (NAA). Data from both phantoms and volunteers were included in this analysis, as there was not a significant difference between their ratios. These results are comparable to similar findings by Cunningham et al [1]. Table 2 shows the median SNR values for each metabolite in all volunteers for each pulse sequence, including data reconstructed from only the positive lobe of the symmetric EPSI data. It should be apparent that the combination of positive and negative lobes improves SNR by a factor of approximately √2. Figure 1 shows how the increased FOV from the EPSI sequences can reduce lipid from the scalp aliasing into brain tissue spectra.

Table 1. Median % difference from relative SNR ratio

	Cho	Cre	NAA
EPSI	-22.30	-32.22	-24.50
EPSI pos	-42.05	-46.89	-46.20
EPSI w/ ramps	-24.12	-33.18	-19.36
Flyback	-17.99	-20.11	-27.85
Int Flyback	-31.22	-28.86	-29.60

Table 2. Median SNR values for each pulse sequence in volunteers

	Cho	Cre	NAA
EPSI	9.66	7.30	18.10
EPSI pos	7.54	5.52	14.05
EPSI w/ ramps	8.52	5.92	15.87
Flyback	9.26	7.77	17.87
Int Flyback	8.65	7.43	15.42
CSI	17.71	15.83	33.55

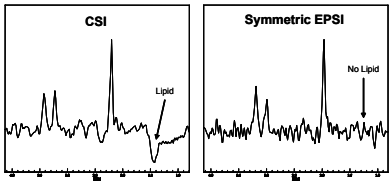

Figure 1. Extended FOV in EPSI pulse sequence prevents lipid aliasing. Spectrum on the left was acquired with a 12cmx12cmx8cm FOV in 21 minutes. Spectrum on the right was acquired with 16cmx16cmx12cm FOV in 9.5 minutes.

DISCUSSION:

By applying an oscillating gradient during data acquisition, one can obtain a larger spatial FOV data set in less time than traditional CSI pulse sequences. This can be beneficial to prevent spatial aliasing of unwanted spectra. A faster acquisition is also clinically beneficial by reducing patient discomfort and allowing time to acquire other MR data. In addition, due to the decreased acquisition time, TR's of the EPSI sequences can be increased to reduce any T1-weighting the spectra may have. Hurd et al. have shown, in normal gray matter, choline, creatine, and NAA have respective T1's of 1.1, 1.55, and 1.65 seconds at 3T [2]. If the 1.1 second TR's used here are doubled in the symmetric or flyback EPSI pulse sequences, but NEX is reduced to one, data can be acquired in the same amount of time, possibly with similar SNR results but have much less T1-weighting. However, increasing TR's in already extremely long CSI scans can be difficult to justify. Interleaved flyback EPSI may also be utilized to improve spatial resolution or increase spectral bandwidth. Additionally, using data acquired on the symmetric EPSI waveform ramps can also improve spatial resolution without significantly increasing SNR costs.

The results here demonstrate reliable data acquired from EPSI pulse sequences. Although there is a reduction in SNR of 18-33% relative to CSI, the data is still clinically useful, and the benefits of the EPSI sequences may outweigh the SNR costs in a clinical setting.

CONCLUSION:

Due to time benefits, reduction of lipid aliasing, and the possibility of reducing T1-weighting in the spectra, echo-planar spectroscopic techniques can be very useful for calculations of spatial metabolite levels in the human brain. Further studies will apply these 9.5 minute EPSI techniques in order to clinically evaluate their usefulness.

REFERENCES AND ACKNOWLEDGEMENTS: This study was supported by LSIT-01-10107 and UC Dean's Health Science grants.

[1] Cunningham CH, et al. Magn Reson Med. 2005 Nov; 54(5):1286-9. [2] Hurd R, et al. Magn Reson Med. 2004 Mar;51(3):435-40.