High Speed MR Spectroscopic Imaging of Cancer Using Flyback Echo Planar Encoding

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Introduction:

Three-dimensional MR spectroscopic imaging (MRSI) has been used extensively in brain tumor and prostate cancer patients for assessment of tumor extent, planning treatment and therapy follow up (1-2). One limitation of this technique is the time needed to acquire large volume 3D MRSI datasets when using conventional phase encoding in three directions to traverse k-space. With the higher field MR systems and improved coil arrays providing increased SNR, MRSI data can be acquired with higher spatial resolution. However, scan time required for 3D high resolution MRSI data with adequate spatial coverage may be prohibitively long for clinical exams. Also, with increased SAR and longer T1 relaxation times at higher field, scan time may further increase by the necessity of using longer TR. Approaches such as EPSI and spiral SI have been applied to provide higher speed MRSI data acquisition (3-4). But limitations such as susceptibility artifacts, low spectral bandwidth, and difficult data reconstruction reduce the applicability of these techniques in the clinical setting. The flyback k-space trajectory has been shown to provide robust data acquisition with reduced flow and off resonance artifacts in cardiac imaging (5). In this study, a PRESS sequence that incorporates flyback echo planar readout trajectory was applied in brain tumor and prostate cancer patients to provide large array, high spectral resolution 3T MRSI data in 8.5 minutes.

Methods:

Two flyback echo planar trajectories were designed and implemented. The first trajectory was designed for 976 Hz spectral bandwidth and 4.9 mm minimum spatial resolution. The second trajectory is designed for 988 Hz spectral bandwidth and 9.8 mm minimum spatial resolution. All studies were acquired on a GE 3T scanner. A modified PRESS sequence incorporating the first trajectory was applied in four prostate cancer patients. The body coil was used for excitation and a custom build rigid endorectal coil in conjunction with a pelvic phase array coil was used for signal reception. MRSI data was acquired with 16x1x8 phase encoding matrix using flyback echo planar readout in the Y-gradient direction (effective matrix: 16x16x8) and a spatial resolution of 0.15 cc. TE was 85 ms and TR was 2 s. Data acquisition time was 8.5 min with 2 NEX. The MRSI sequence incorporating the second trajectory was applied in five brain tumor patients. An 8-channel head array was used for signal reception. The MRSI data was acquired with 16x16x1 phase encoding matrix using flyback echo planar readout in the Z-gradient direction (effective matrix: 16x16x16) and a spatial resolution of 1 cc. The TE was 30 ms (n = 2) or 144 ms (n = 3) and TR was 2 s. Acquisition time was 8.5 min with 1 NEX. MRSI data was processed offline using custom analysis software. K-space points on the constant gradient readout lobe in the flyback dimension were selected and after these points were reordered, the data processing was similar to standard MRSI data set. The time delays for the k-space points in the flyback direction were easily corrected by a phase shift in the transformed data.

Results and discussion:

Clinically useable quality spectra free of artifact were acquired in both brain tumor and prostate cancer patients in 8.5 min with a PRESS sequence incorporating flyback echo planar encoding (Fig. 1-2). Greater k-space coverage was achieved in both brain tumor and prostate cancer patients using flyback echo-planar MRSI in much shorter scan time comparing to conventional phase encode method. In addition, the time reduction achieved by the flyback MRSI allowed the use of longer repetition time (2s), reducing saturation of the metabolite signals with longer T1 at higher field. The processing time required for the 8-channel array data set was ~5min on a standard workstation. Currently, scan times for clinical MRSI in brain tumor or prostate cancer studies are ~17 min. With the flyback echo planar MRSI, scan time could be reduced by 50% with even greater spatial coverage.

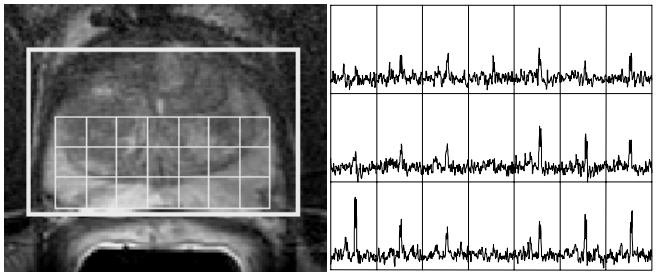

Figure 1. High spatial resolution (0.15 cc) MRSI data acquired with flyback MRSI. 16 x16 x 8 data matrix provide complete coverage of the prostate gland. TE = 85ms, TR = 2s and NEX = 2. Total scan times was 8.5 min.

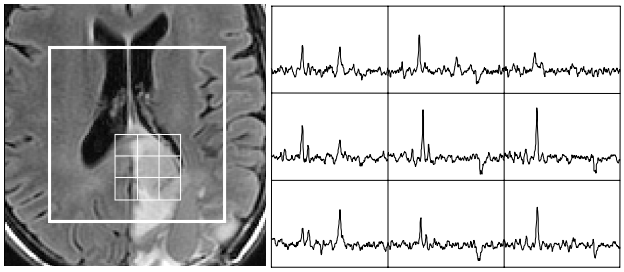

Figure 2. Flyback echo planar MRSI data acquired from patient with grade 4 GBM. Significantly elevated choline and reduced NAA as well as lactate was observed in the region of the tumor. TE = 144ms, TR = 2s.

Conclusion:

Flyback echo planar MRSI was shown in this study to provide robust, fast data acquisition of high spatial-spectral resolution MRSI data, without observable off-resonance or flow artifacts. It also provided MRSI data that could be reconstructed without extensive regridding or density correction. This technique can be extended in a variety of MRSI acquisitions for different applications such as spatially-resolved 2D-J resolved spectroscopy, ultra high resolution 3D MRSI with large matrices, or spectral-editing.

References:

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Acknowledgement: NIH RO1-CA59897 and LSIT 01-10107