COMPRESSED SENSING BASED ECHO PLANAR 3D MRSI USING SHORT ECHO TIME: A PILOT EVALUATION USING A PROSTATE PHANTOM

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Target audience: MR Physicist, Pulse sequence developers and Clinicians

Introduction: MRSI of the prostate is typically performed with a combination of point-resolved spectroscopy (PRESS) (1) volume localization and three dimensional (3D) MRSI (2) rather than the traditional single-voxel or two-dimensional (2D) MRSI technique used for many years in brain imaging. Three-dimensional MRSI requires phase encoding in three dimensions, conventionally known as frequency, phase, and slice. Acquisition time and coverage of the prostate are the main considerations in choosing the matrix dimensions. The MRSI data can be acquired with higher spatial resolution leading to long total acquisition time. Conventional prostate MRSI study with average weighted encoding uses long echo time (TE) with short repetition time (TR) allowing the observation of a reduced number of metabolites without accurate quantitation. Long TEs are used for the 3D MRSI due to the addition of MEGA radio-frequency pulses for both water and lipid suppression. In echo-planar spectroscopic imaging (EPSI) (3,4), an alternating gradient, which simultaneously encodes space and chemical shift (time), is applied along one of the spatial (readout) directions, thereby reducing phase encoding dimensions from three to two thereby increasing speed. MRI is well suited for compressed sensing (CS), and there are significant benefits in imaging speed and reduced costs, thereby improving patient care (5,6). A major challenge in designing CS data acquisition methods for MRI is in implementing non-uniform under sampling (NUS) densities that result in incoherent aliasing while providing data sparsity in a transform domain, such as wavelets, curvelets, etc. The goal of the present study was to implement a novel NUS based 3D EPSI on a 3T MRI/MRS scanner and to evaluate the performance using a prostate phantom.

Materials and Methods: A schematic diagram of NUS based 3D EPSI sequence, compiled and implemented on the Siemens 3T MRS scanner, is shown in Figure 1 where three spatial encodings and one spectral dimension were used. In the 3D EPSI sequence, the EPSI readout simultaneously acquires one spatially encoded dimension (k_x) and one spectral dimension (t), leaving the remaining the two spatial dimensions (k_y and k_z, respectively) incremented sequentially. We propose the use of NUS in the remaining k_y-k_z plane, using CS to reconstruct the equivalent missing data to a fully sampled 3D EPSI acquisition.

To determine the feasibility as well as evaluate the performance of the CS reconstruction, numerous prospective 2X undersampling and reconstructions were performed on a prostate 3D EPSI of nine phantom dataset and two healthy volunteers using external phased array coil. A 500mL prostate phantom was prepared containing the following metabolites at physiological concentrations as reported in healthy human prostate (7): Cit, 50 mM, Cr, 5 mM, Ch, 1 mM, Spm, 6 mM, mI, 10 mM, PCh, 2 mM, Tau, 3 mM, Glu, 4 mM, Gln, 2.5mM and sI, 0.8 mM. The dataset was localized with a field of view (FOV) of 24x24x16 cm^3 for an individual voxel volume of 1.5 cm^3; 256 bipolar gradient echo pairs (t samples) were collected with bandwidth of 1190 Hz. A non-water-suppressed 3D EPSI data using one average was used for eddy current and phase correction of the suppressed data. With pulse repetition time/echo time = 1500/30 ms and 8 averages, the 3D EPSI phantom scan duration was 12 minutes. Global water suppression was performed just before the PRESS localization.

Results: Both the non-water suppressed (NWS) and water suppressed (WS) scans were separated into positive (even) and negative (odd) subsets first and reorganized into k_x-k_y-k_z-t matrices. Reconstruction of the NUS based 3D EPSI data sets was done offline using a custom MATLAB software package. Fig.2. shows the extracted 1D spectrum from the central voxel from the prostate phantom (volume of 1cm^3). We were able to detect and quantitate glutamate/glutamine (Glx), spermine, myo-inositol in addition to citrate, choline and creatine. The metabolite quantitation was done by Felix peak integral quantitation method. The mean and standard deviation of metabolites with respect to creatine were: Citrate (12.642±3.230), spermine ((1.108±0.167), choline (0.619±0.069), myo-inositol (1.816±0.345) and Glx (2.239±0.267). The expected and calculated experimental metabolite ratios with respect to creatine are shown in Fig.3.

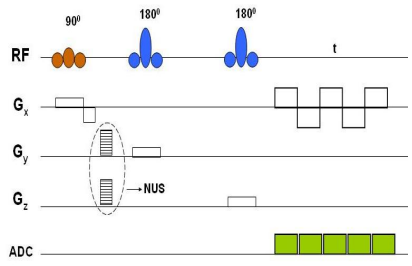

Fig.1. NUS based 3D EPSI sequence

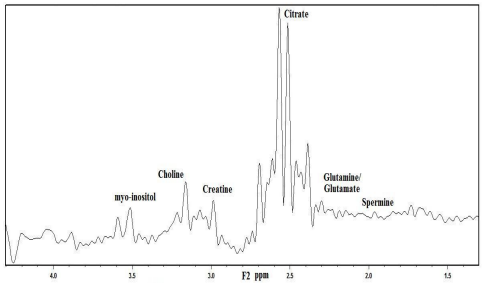

Fig.2. An extracted spectrum from the central voxel

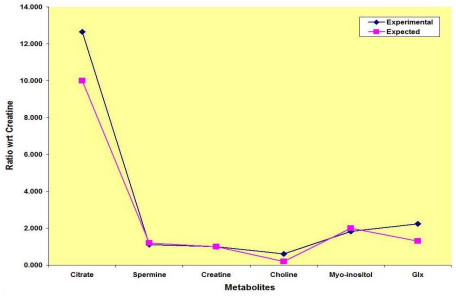

Fig.3. Comparison of experimental and expected metabolites ratios wrt creatine

Discussion: By using CS based reconstruction, we have demonstrated a potential reduction in acquisition time by up to 80% for proton MRSI, with negligible loss of information as evaluated on the basis of clinically relevant metrics . The NUS 3D spatial +1D spectral encoded EPSI sequence recorded short TE-based spectra from multiple regions of a prostate phantom and showed more metabolites in addition to the normally detected citrate, creatine, choline and spermine.

Conclusion: The NUS based 3D EPSI data using CS reconstruction to detect and quantify metabolites less T2-weighted than the earlier 3D MRSI sequences using conventional phase encoding. It could be employed to help detect prostate cancer more accurately thereby eradicating negative biopsies, evaluate cancer stage noninvasively, and guide treatment selection. Our current effort is focused on developing an optimal sequence with interleaved water-suppressed metabolite and unsuppressed water acquisition.

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