COMPRESSED SENSING OF NON-UNIFORMLY UNDERSAMPLED 3D EPSI OF HEALTY BRAIN

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Target audience: Researchers interested in MR Spectroscopy and application of compressed sensing in healthy human brain *in vivo*

Introduction: Conventional MR Spectroscopic Imaging (MRSI), where phase encoding gradients are incremented per repetition time, is the most commonly used MRSI method with a drawback of long scan time (1, 2). Fast MRSI is highly desirable in order to decrease scan time, increase volume coverage and reduce motion sensitivity. Acceleration was demonstrated using echoplanar spectroscopic imaging (EPSI) (3). Compressed sensing (CS) is a recently developed fast imaging method that exploits sparsity of MR images to reconstruct under-sampled data. As an alternative of acquiring the fully-sampled data (MRI or MRSI) and compressing it afterward, compressed sensing applies the fact than the data is usually sparse under an appropriate basis and reconstructs this sparse representation from undersampled data. The number of necessary samples in practice is approximately three to five times the number of sparse coefficients, which represents a considerable acceleration if the number of sparse coefficients is much less than the total number of points (4, 5). Acquisition of three dimensional EPSI using a non-uniform undersampling (NUS) scheme and post-processing the 3D EPSI data using compressed sensing are yet to be demonstrated. Hence, a major goal of the study was to implement and evaluate the performance of semi-LASER NUS based 3D EPSI in healthy brain using compressed sensing reconstruction by minimizing total variation method.

Materials and Methods: To establish the applicability in a clinical setting, the semi-LASER NUS-based 3D EPSI acquisition and CS reconstruction were tested in a brain phantom and four healthy subjects using a 3 Tesla MRI scanner (Skyra, Siemens Medical Solutions, Erlangen, Germany) equipped with a 16-channel head 'receive' coil. Written informed consent was obtained before study participation and the data were acquired in accordance with an IRB approved protocol. CS reconstruction was then performed by solving the total variation minimization problem using the linearized Bregman iteration. The 3D EPSI parameters are: FOV = 160x160x80 mm^3, image matrix = 16x16x8, spectral width = 1190 Hz, number of spectral points = 256, TE = 41ms, TR = 1.5s, Avg=12. Data acquisition included water-suppressed (WS) and non-water-suppressed (NWS) scans (~20 mins). The NWS scan was used as a reference to perform eddy current and spectral phase correction. A 2X NUS scheme was imposed along the two spatial dimensions (ky and kz). Extractable individual voxel volume in human brain was 1.5ml. The phantom and healthy brain semi-LASER 3D EPSI NUS data were extracted and post-processed using homebuilt MATLAB-based (The Mathworks, Natick, MA, USA) library of programs.

Results and Discussion: We were able to detect and quantitate NAA, Glx, Asp, Lac, GSH, tCh and mI in the following locations: right basal ganglia, left basal ganglia, medial frontal grey, right frontal white, left frontal white, right occipital white and left occipital white regions. The metabolite quantitation was done by a peak integral quantitation method using matlab. We have done retrospective reconstruction of fully encoded in vivo data, which showed high fidelity for accelerations up to 2 as determined by the low RMSE. The in vivo fully encoded, 2x and 4x reconstructed NAA map of eight slices are shown in Fig.1a. The mean and standard deviation of metabolites with respect to creatine in (2x of 3D EPSI NUS data) various region of healthy brain are shown in the Fig.1b. The MRI and 3DEPSI voxel localization and multivoxel display of 35 years old healthy brain was shown in Fig.1c and d with the volume of interest is 1.5cm^3. The mask was generated using a non-uniform probability density function that favored the center of k-space. Our results showed that compressed sensing reconstructed 3D EPSI had higher SNR than the original data due to the denoising effect. But, peak height ratios were similar between the original and compressed sensing datasets. The major metabolites shows the overall quality and resolution of the reconstructed 3D EPSI spectra were comparable to the fully sampled dataset for the brain phantom retrospective and prospective studies, indicating a successful implementation of CS in reconstructing the NUS-based 3D EPSI data.

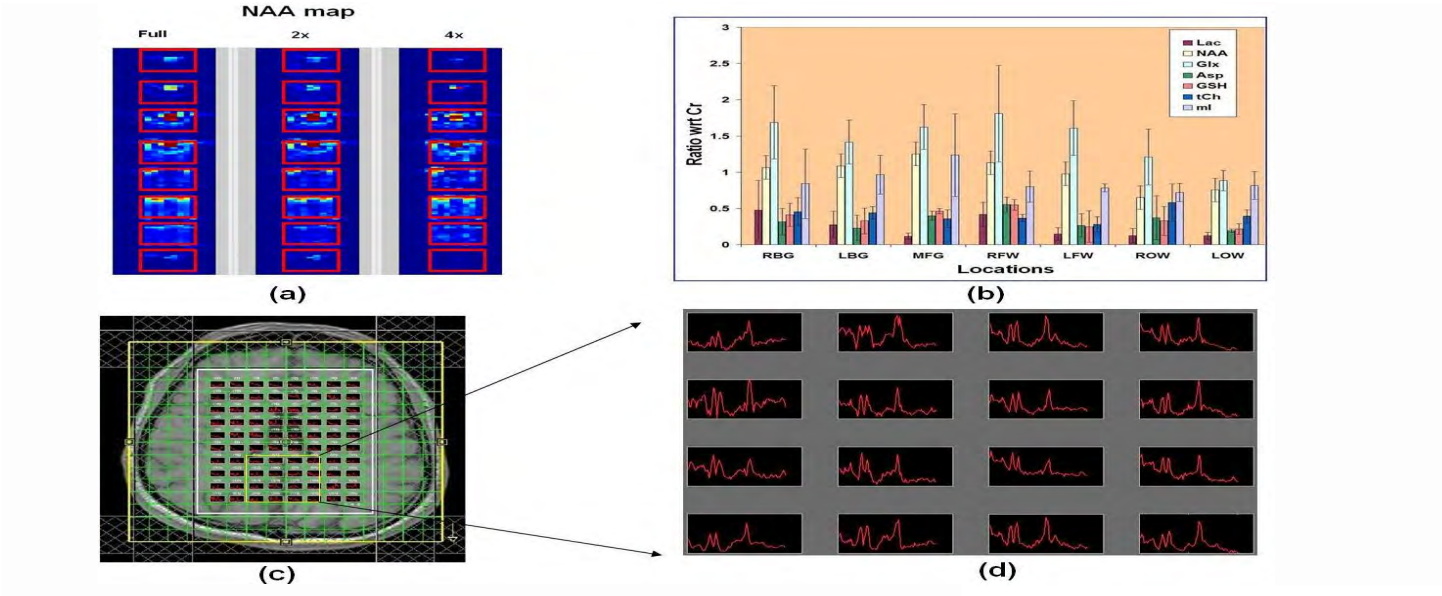

Fig.1. (a) Retrospective reconstruction of NAA slice maps (b) The mean and standard deviation of metabolite ratios with respect to creatine in (3D EPSI NUS data of 2x) various region of healthy brain (c) MRI and 3D EPSI voxel localization (d) Selected multivoxel display of a 35 years old healthy brain

Conclusion:
We have presented a technique combining EPSI with compressed sensing reconstruction (2x undersampling) and have shown that this method yields a better spatial profile without compromising spectral quality. Using further optimization of CS reconstruction may enable more acceleration. By using parallel imaging like SENSE (6), the sampling density and reconstruction algorithms may allow even greater reduction in the minimum amount of data required for reconstruction and may further shorten scanning times.

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