NONUNIFORMLY UNDER-SAMPLED (NUS) ECHO PLANAR J-RESOLVED SPECTROSCOPIC IMAGING (EP-JRESI) OF PROSTATE CANCER PATIENTS AND COMPRESSED SENSING RECONSTRUCTION

Rajakumar Nagarajan[1], Daniel Margolis[1], Stevan S Raman[1], Nidhi Jain[1], Robert E Reiter[2], and M Albert Thomas[1]

[1]*Radiological Sciences, University of California Los Angeles, Los Angeles, CA, United States,* [2]*Urology, University of California Los Angeles, LOS ANGELES, CA, United States*

Target Audience: Basic Scientists and Clinical Researchers Focused on Non-invasive Cancer Diagnosis especially prostate cancer

Introduction: Prostate cancer (PCa) is the second leading cause of cancer death in American men, behind only lung cancer. About 1 man in 36 will die of prostate cancer. Due to its prevalence in the male population as well as its unpredictable clinical course, early diagnosis and detection have become crucial for reducing morbidity and mortality. MR Spectroscopy (MRS) has evolved as a powerful non-invasive tool for early detection of PCa through the detection of normal and abnormal biochemicals. Single- and multi-voxel based 1D MRS approaches have reported three prostate metabolites only, such as citrate (Cit), choline (Ch), spermine (Spm) and creatine (Cr) (1,2). This was due to the long echo time (TE >100ms) and limited 1D spectral quantitation approaches used. A single-voxel based two-dimensional (2D) J resolved spectroscopic sequence (JPRESS) has been implemented on both 1.5T and 3T MRI/MRS scanners demonstrating improved spectral dispersion due to the added spectral dimension (3,4). Since the JPRESS sequence enables recording a spectrum from one location only, there is a need for recording the 2D spectra from multiple locations. Reports show that MRI is well suited for compressed sensing (CS), and there are significant benefits in imaging speed and reduced costs (5). A non-uniformly undersampling (NUS) four dimensional (4D) echo-planar J-resolved spectroscopic imaging (EP-JRESI) sequence was recently implemented for acquisition with CS reconstruction and pilot data was shown in healthy prostates using the external phased-array coil assembly (6). The goal of this work is to investigate the underlying biochemical changes in PCa using the NUS EP-JRESI acquired data with an endorectal coil for better sensitivity and post processing using CS-based reconstruction.

Methods: Eleven PCa patients (55-77 years) with Gleason scores (GS) of (GS 3+3, 3+4, 4+3 and 4+4) were selected for the endorectal MRI/MRS study. The prostate specific antigen (PSA) values for the PCa patients ranged from 4.3-9.1 ng/ml. The entire study was approved by the institutional review board (IRB), and informed consent was obtained from each human subject. A 4D NUS EP-JRESI sequence was implemented on a Siemens 3T Trio-Tim scanner (Siemens Medical Systems, Germany) running on the VB17A platform and the volume of interest (VOI) was localized using three slice-selective radio-frequency (RF) pulses (90^0-180^0-180^0). The total duration for acquiring a fully sampled 4D EP-JRESI data (TR of 1.5s, 16ky*16kx, 100t_1, 512t_2) can be 40 minutes long. The CS-based reconstruction will enable a stable and accurate reconstruction from the NUS based EP-JRESI data (25% of t_1 and ky increments) with a reduced acquisition duration. The parameters for the EP-JRESI was: TR/TE/Avg = 1.5s/30ms/1-2, 16 phase encoding steps, 512 complex points with an F_2 bandwidth of 1190Hz. For the second dimension (F_1), 64 increments with bandwidths of 1000Hz were used. A 25% NUS was imposed along the incremented spectral and spatial dimensions. Phantom measurements were also conducted for sequence optimization. The individual voxel volume in human prostate was 1ml from the NUS EP-JRESI 4D dataset. Two sets of data were collected, one with water suppression (WS) with a total scan time of 6-12 mins and second with non water suppression (NWS) using 1 average only.

Results: Fig.1. shows 1ml 2D JPRESS spectra extracted from the 4D NUS EP-JRESI data: i) a prostate phantom containing 10 metabolites such as citrate (Cit), creatine (Cr), phosphocholine (PCh), glutamate (Glu), glutamine (Gln), myo-inositol (mI), taurine (Tau), free choline (Ch) and spermine (Spm) (top); ii) a healthy location of a 71 year old PCa patient with GS 3+3 (bottom). Fig.2. shows an axial T_2W MRI slice recorded in a 71 years old PCa patient showing the multi-voxel EP-JRESI grids; extracted 2D JPRESS spectra of malignant voxels (ii) and iii), and the healthy voxel in the peripheral zone (iv). Following findings were observed in the tumor spectra: significantly increased Ch, significantly decreased Cit, and increasing/decreasing trends of the following metabolites (Spm, myo-inositol (mI), taurine (Tau) and scyllo-inositol (sI) demonstrating the increased power of the 4D NUS EP-JRESI technique with more metabolite changes than the commonly reported few metabolite changes using the conventional 3D average-weighted MRSI technique with heavily T_2-weighted metabolite detection.

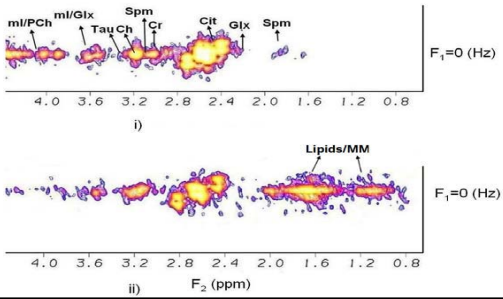

Fig.1. Extracted (1ml) 2D JPRESS spectra in vitro and in vivo from: i) a prostate phantom containing 10 metabolites; ii) a healthy location of a 71 years old PCa patient with GS 3+3

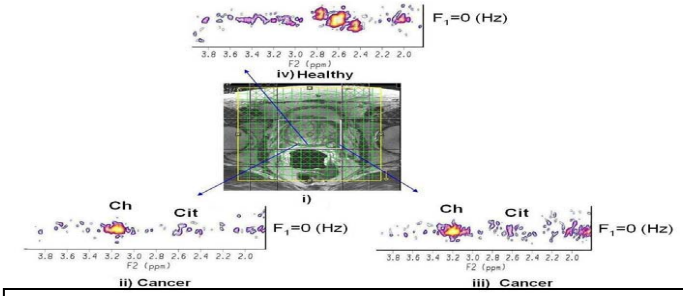

Fig.2.A 71 years old PCa patient axial T_2W MRI slice showing the multi-voxel EP-JRESI grids; extracted 2D JPRESS spectra of malignant voxels (ii) and iii), and the healthy voxel in the peripheral zone (iv)

Discussion: As shown in Fig.2, abnormal spectra from the left and right ends of the 71 years old PCa patient as conformed by biopsy determined Gleason scores of 3+3. Extracted tumor spectra of a 61 y.o. patient with two lesions with different GS3+4 and GS 4+3 showed significantly increased Ch and significantly decreased Cit, Spm, mI, Tau and sI demonstrating more metabolite changes than the commonly reported few metabolite changes using the conventional 3D MRSI technique. It was also seen that the lesion with GS 4+3 showed more significant changes of metabolites with elevated Glx (Glu+Gln) in agreement with a recent HR-MAS analysis of radically resected prostate specimens by Gribbestad and co-workers (7). Presence of an additional peak in GS 4+3 at 2.8ppm was indicative of the elevated ω6 fatty acids as reported recently (8).

Conclusion: The 25% undersampled CS-reconstructed EP-JRESI data using the endorectal "receive" coil showed excellent 2D J-resolved spectral quality demonstrating the clinically acceptable acquisition duration (6-12 minutes) with 1ml voxel resolution. With further optimization of the NUS acquisition and the non-linear reconstruction using CS, there is a hope of further improving voxel resolution (<1ml).

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