Implementation of Localized Two-Dimensional Homonuclear Correlated MR Spectroscopy (L-COSY) Sequence for Prostate Study at 7T

H. Liu[1], H-M. Baik[1], M. J. Hamamura[1], J-H. Chen[1,2], M-Y. Su[1], T. Muftuler[1], and O. Nalcioglu[1]

[1]Tu and Yuen Center for Functional Onco-Imaging, University of California, Irvine, Irvine, California, United States, [2]Department of Radiology, China Medical University Hospital, TaiChung, Taiwan

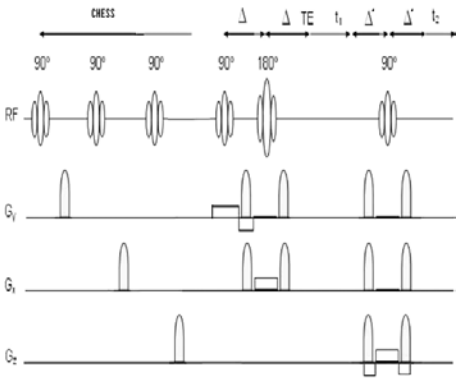
Purpose

Kenneth et al [1] and Marinette et al [2] have shown in their studies that normal or benign prostatic tissue contain high polyamine spermine levels, which are decreased in prostate cancer tissue by using 2D J-resolved MR spectroscopic (JPRESS) sequence. The polyamine spermine, which plays a role in cell proliferation and differentiation, may provide additional information for early diagnosis or risk assessment for prevention trials of prostate cancer. However, 2D JPRESS is sensitive to the strong coupling effect, which results in more complex of 2D cross-peak pattern for prostate metabolites. Conventional 1D MRS prostate spectra has the problem of significant overlap of creatine, spermine and choline in the spectral range of 3.0~3.2ppm. Compared to the 2D JPRESS, 2D **CO**rrelated MR **S**pectroscop**Y** (COSY) technique provides a better spectral dispersion of J-cross-peaks, although it requires a larger spectral window to be sampled during the evolution period [1]. The purposes of our study were: 1) To implement a localized 2D COSY sequence (L-COSY) on a 7T MRI/MRS scanner and to record L-COSY spectra in the prostate phantom. 2) To demonstrate that 2D L-COSY MRS can clearly resolve the polyamine spermine peaks from the neighboring overlapping of choline and creatine.

Methods

All experiments were performed using a 15-cm, horizontal-bore, 7T magnet (Oxford Instruments Limited. UK), equipped with a SMIS console (Surrey Medical Imaging System, UK). An in-house made birdcage coil with 65 mm diameter was used for both RF transmission and signal detection. Measurements were performed on a phantom containing a solution with 90 mM citrate, 20 mM spermine, 10 mM choline and 12 mM creatine to mimic prostate tissue (pH =7.0). The conventional single-voxel MRS was acquired by using a point-resolved spectroscopic (PRESS) sequence with CHESS water suppression. The acquisition parameters were TR/TE=2000ms/54ms, voxel size =15X15X15 mm^3, NSA=512 averages, and 1024 t_2 complex points. A 2D L-COSY sequence with the CHESS suppression was performed (Fig. 1). A voxel selection (15X15X15 mm^3) was acquired by using a CABINET (Coherence trAnsfer Based spIN-Echo specTroscopy) [3] localization scheme (90°–Δ– 180°–Δ– (t_1) – Δ′–90°–Δ′–Acq). A 8-step phase cycling scheme was used on all three pulses in order to minimize the effect of the RF pulse imperfection in conjunction with signal averaging. 2D L-COSY spectra were recorded using the following parameters: TR = 2 sec, minimal TE of 18ms, Δ=8ms, Δ′=6ms, and 128 t_1 increments were used to sample the second frequency dimension (F_1). The raw data was acquired using 1024 complex points and the spectral window along the first dimension was 2.5 kHz, and 1kHz along the second dimension. matNMR software package was employed to analyze the spectra. The raw data was apodized with exponential functions along t_1 and t_2 and zero-filled to 512 x 2048 prior to Fast Fourier Transformation. All 2D spectra were presented as contour plots. The resulting spectrum was displayed in magnitude mode.

Fig1. 2D L-COSY sequence diagram



Results

Figure 2 shows a conventional one-dimensional MR spectrum obtained from the prostate phantom. In the spectrum, spermine multiplets at 3.10 ppm were still overlapped with neighboring choline and creatine peaks at 7.0T. However, in the 2D L-COSY MR spectra (Fig. 3), spermine shows two well-separated cross-peaks at (F_2 = 3.1 ppm, F_1 = 1.8 ppm), (F_2 = 1.8 ppm, F_1=3.1 ppm) and (F_2 = 3.1 ppm, F_1 = 2.1 ppm), (F_2 = 2.1 ppm, F_1 =3.1 ppm). The diagonal peaks along $F_1 = F_2$ resembles the conventional 1D spectral resonances.

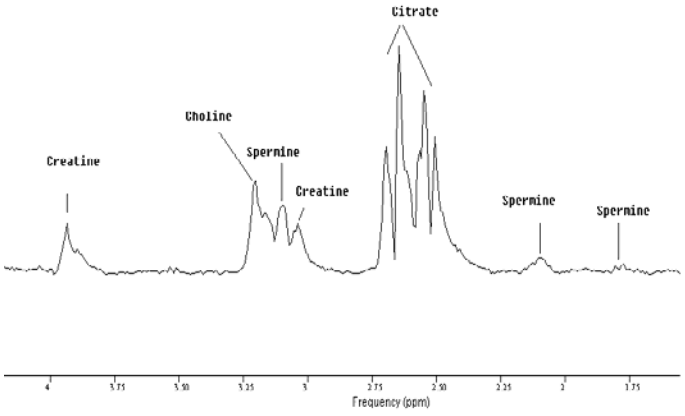


Fig2. 1D conventional Localized ^{1}H PRESS prostate spectra

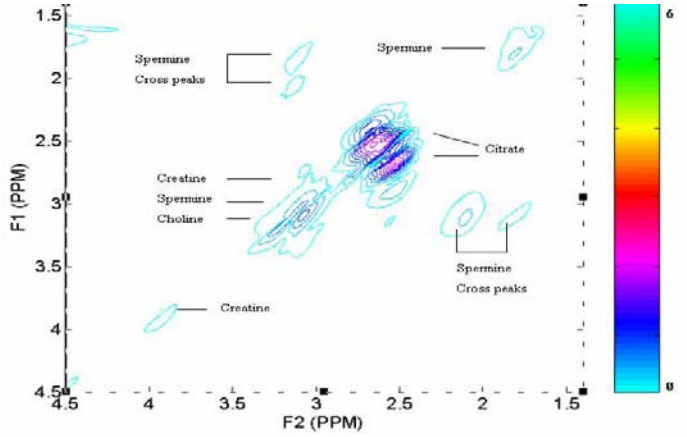


Fig3. 2D L-COSY prostate spectra

Discussions

Present methods for the detection of malignancy in the prostate suffer from various limitations. For prostate studies, polyamine spermine may be a valuable diagnostic biomarker to discriminate prostate cancer from benign prostate or normal tissue. However, the measurement of spermine resonances using a conventional ^{1}H MRS technique in prostate is difficult due to the J-modulation and overlap with other metabolites. Spectral editing and multiple quantum (MQ) techniques can be used to differentiate the overlapping resonances. However, spectral editing is limited by selectively detecting only one metabolite, whereas MQ techniques suffer from reduced signal. Moreover, 2D JPRESS technique has a weakness in signal detection due to the strong coupling effect. On the other hand, COSY method provides a better spectral dispersion for resolving metabolites of interest. Our preliminary result suggests that 2D L-COSY could be implemented for prostate study. Spermine cross-peaks were showed well separated at 2.1ppm/3.10ppm and 1.8ppm/3.10ppm (Fig. 3). The overlap of spermine with neighboring choline, creatine is unequivocally resolved. With the successful implementation of this sequence, we are initiating a study on mice with prostate carcinoma in parallel with a human trial on 3T. We are currently recruiting patients with confirmed prostate cancer who will receive prostectomy. The spermine peak analyzed by 2D L-COSY will be compared to that analyzed from the corresponding tissue specimens for validation. If successful, this may be incorporated in diagnosis or chemoprevention trials.

References: 1. Yue et.al. MRM 2002; 47:1059-1064. 2. Van der Graaf et al. MAGMA 2000; 10:153-159. 3. Thomas et al. MRM 2001; 46:58~67.

Synopsis

In this study we implemented and evaluated a localized 2D correlated MR spectroscopic sequence (2D L-COSY) on 7T by using prostate phantom. Spermine may be a potential biomarker for differentiating the prostate cancer, BPH and healthy prostates. Due to an added dimension, a localized 2D MR spectrum has a better resolution than a conventional 1D MR spectrum. The pilot results showed that 2D L-COSY peaks due to choline and spermine could be resolved. The sequence will be incorporated into diagnosis or chemoprevention trials, for in-vivo monitoring of polyamines in future animal and human studies.