4D ECHO PLANAR CORRELATED SPECTROSCOPIC IMAGING AND DWI OF BREAST CANCER

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Target audience: Researchers interested in breast magnetic resonance imaging (MRI) and multi-dimensional MR Spectroscopic Imaging (MRSI)

Introduction: In vivo proton (^{1}H) MR spectroscopy enables non-invasive detection of choline containing compounds, water and lipid resonances in breast cancer (1-3). One dimensional (1D) MRS and a single slice-based two-dimensional (2D) or volume-based three dimensional (3D) MRSI suffer from overlapping metabolites and also, the MRSI acquisition time is long. Similarly, localized 2D correlated spectroscopy (L-COSY) suffers from a voxel placement and a long acquisition duration. Echo-planar spectroscopic imaging (EPSI) can greatly shorten the acquisition duration. Combining a second spectral dimension with the EPSI sequence will increase the spatial-spectral coverage using echo planar correlated spectroscopic imaging (EP-COSI) which records two spectral and two spatial dimensions. The role of diffusion weighted imaging (DWI) in breast cancer has been reported in many studies (4,5). The DWI suffers from poor specificity since the apparent diffusion coefficient (ADC) cannot distinguish benign from malignant lesions due to tumor cellularity. Two major goals of this work were as follows: 1) to implement and validate 4D EP-COSI in breast cancer and healthy women, and 2) to correlate lipid and choline changes derived from the 4D EP-COSI spectra with ADC.

Materials and Methods: The 4D EP-COSI sequence was implemented on a Siemens 3T Tim-Trio MRI/MRS scanner (Siemens Medical Systems, Erlangen, Germany) running on the VB17A platform and the volume of interest (VOI) was localized using three slice-selective radio-frequency (RF) pulses (90^0-180^0-90^0) as described recently (6). The parameters for the EP-COSI acquisition were: TR/TE/Avg = 1.5s/30ms/1, 1024 bipolar echoes with each echo sampling 16 kx and 16 ky, FOV= 16cm. The bandwidth of directly detected spectral dimension (F2) was 1190Hz and for the indirect second dimension (F1), 50 increments with bandwidths of 1250Hz was used. The individual voxel volumes in the 4D EP-COSI data were approximately 2.0ml. Two sets of EP-COSI data were collected, first with water suppression (WS) for 20 minutes and second, with non water suppression (NWS) for approximately 1.25 minutes. Oil phantom measurements were also used for the 4D EP-COSI sequence optimization. Twelve healthy subjects (mean age of 43 years) and breast cancer patients (7 benign patients with a mean age of 42 years and 4 malignant patients with a mean age of 54 years) underwent acquisition of MRI/DWI and EP-COSI with a dedicated 4-channel phased array breast 'receive' coil. For voxel placement, axial, coronal and sagittal T1- and T2-weighted MR images were used, and the 4D EP-COSI spectra were recorded in the fatty, glandular and ductal areas of healthy and malignant breasts. For the DWI, 2D spin-echo echo-planar imaging (EPI) sequence (TR/TE of 3800/93ms; data matrix, 192 × 192; signal average, 3; slice thickness, 3 mm; distance factor, 20%) in the axial plane was used. Sensitizing diffusion gradients in three orthogonal directions with b values of 50 and 800 s/mm^2 were applied. The ADC maps were created automatically by the system from the trace-weighted images with b values of 50 and 800 s/mm^2 .

Results: Fig.1(a) shows the MRI with 4D EP-COSI voxel location of a 50 yo. healthy woman volunteer. 2D COSY spectra from multiple voxels are shown in Fig.1b. The extracted 2D COSY spectrum (red box in b) from the fatty breast region is shown in Fig.1c. The metabolites ratios of healthy, benign and malignant subjects are shown in Fig.1d and e. The ADC values derived from DWI of healthy, benign and malignant subjects are shown in Fig.1f. The 4D EP-COSI spectrum recorded in the lesions of the subject diagnosed with invasive breast carcinoma showed decreased peaks representing the protons of methyl, methylene, water, methyl fat (FMETD), methylene fat (FAT1), olefinic fat (UFD), and a peak due to the tri-methyl protons of choline (Cho), which was not in detectable in healthy breast tissues. There were symmetric cross peaks of unsaturated fatty acids, namely cross peaks right (UFR), unsaturated fatty acids cross peaks left (UFL) and triglyceryl fatty cross peak (TGFR) between the methylene and tri-glyceryl backbone protons of saturated and unsaturated fatty acids.

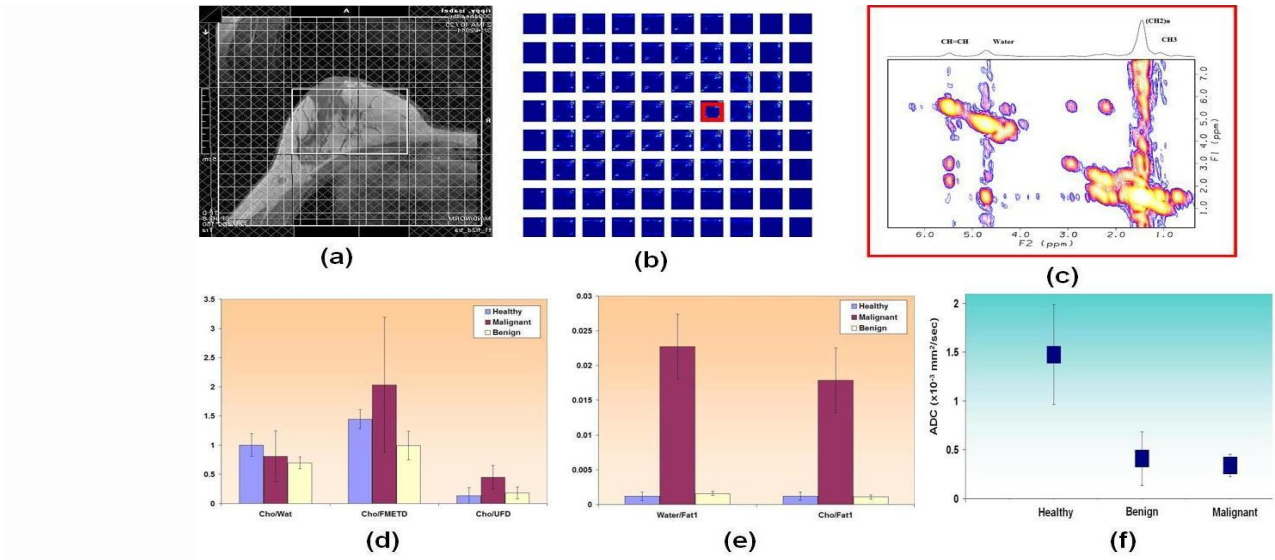

Fig.1. (a) MRI with 4D EPCOSI voxel location (b) Multiple 2D MRS spectra from each voxel (c) Extracted 2D COSY spectrum from tumor location (d) &(e) Metabolites ratios of healthy, benign and malignant subjects (f) ADC map of healthy, benign and malignant subjects

Discussion: Following metabolites ratios showed statistically significant changes ($p<0.05$) between these three groups: Wat/Fat1 and Cho/Fat1 (between healthy and malignant); Cho/water and Cho/FMETD (between healthy and benign); Cho/Fat1 (between benign and malignant). The difference in ADC values between healthy and benign as well as healthy and malignant showed statistically significant ($P<0.05$). In agreement with previous reports (4-5), the ADC values were overlapping between benign and malignant breast lesions. MR Spectroscopic changes were detectable in multiple breast regions using the 4D EP-COSI sequence. However, the outcome of this pilot study has a limitation due to the small number of malignant and benign subjects.

Conclusion: A major outcome of this pilot study is that the 4D EP-COSI enables a single slice coverage of the breast facilitating recording of multi-voxel based 2D MRS than the previously reported single-voxel based L-COSY (7). The 4D EP-COSI data offers improved spectral dispersion and sensitivity compared with 1D MRS.

Acknowledgement: An Idea Expansion grant (W81XWH-10-1-0743) from the Congressionally Directed Medical Research Programs (CDMRP) Breast Cancer Research Program (BCRP).

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