Proton-Echo-Planar-Spectroscopic-Imaging (PEPSI) in Human Breast

C. Zhao[1], P. Bolan[2], L. Sillerud[3], M. Royce[3], A. Wallace[3], S. Eberhardt[3], R. Rosenberg[3], P. Heintz[3], L. Lesley[3], and S. Posse[3]

[1]University of New Mexico, Albuquerque, New Mexico, United States, [2]University of Minnesota, [3]University of New Mexico

INTRODUCTION

MR single voxel spectroscopy (MRS) to measure Choline in breast tumors has shown promise as a diagnostic adjunct to dynamic contrast-enhanced MRI exam. MRS improved the sensitivity, specificity, and accuracy for all readers, and improved the inter observer agreement between the readers [1,6]. However, single voxel spectroscopic techniques do not allow characterization of lesion heterogeneity and multi-focal lesions. Feasibility of MR spectroscopic imaging (MRSI) was demonstrated by Jacobs et al. [2]. However, conventional MRSI is time consuming and artifacts due to chest wall motion and overwhelming lipid resonances make spectral quantification challenging. Here, we describe the use of 2D and 3D Proton-Echo-Planar-Spectroscopic-Imaging (PEPSI) [3,4] in the breast to increase encoding speed and volume coverage. A navigator acquisition was integrated into the water suppression module to monitor frequency shifts from chest wall motion. Preliminary results demonstrate high quality 2D and 3D mapping of lipid resonances.

METHOD

The PEPSI pulse sequence consists of the following modules: water suppression with integrated navigator data acquisition, outer volume suppression, spin-echo RF excitation with MEGA lipid suppression [5], echo-planar readout with 1024 readout gradients, 1087 Hz of spectral width and 2 Hz digital spectral resolution. Spatially resolved navigator data acquisition is performed for each phase encoding step. An echo-planar readout train with 64 readout gradients is integrated into the WET module after the water suppression RF pulse and before the dephasing gradient pulse (Fig.1). Readout gradients are orthogonal to the imaging slice, enabling measurement of frequency shifts in slices parallel to the imaging slice. In vivo experiments in 3 healthy volunteers were performed on 3T MR scanners (Tim Trio, Siemens Medical Solutions) equipped with 4-channel breast coil or 8-channel body array. Automated shimming was performed across the entire PEPSI slice or slab. Non-water TR/TE: 1s/11ms, 64×64 matrix, 286 mm FOV and size of 0.1 cc. Non-water suppressed 3D PEPSI data 64x64x8 matrix, FOV of 286×286×55, 40 mm slab, lipid-suppressed data were acquired with TR/TE FOV, 15 mm slice, resulting in 1.5 cc voxel size. previously [4]. NWS scans with identical pulse used as a reference for phase, frequency and eddy performed using LCModel with simulated basis set

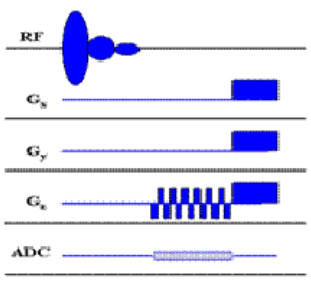
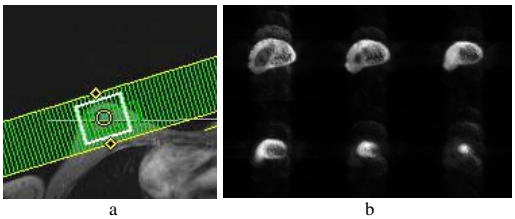
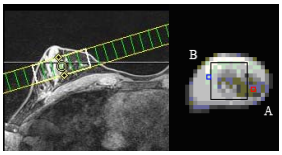


Fig.1 Navigator echo acquisition integrated into the WET module.



a b

Fig.4 a.3D PEPSI slab positioning. b.lipid images from 2nd slice to 7th slice.



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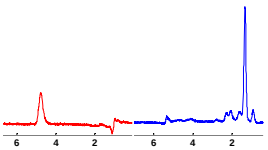

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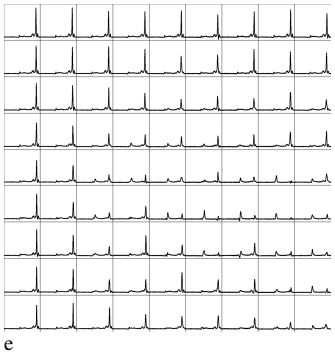
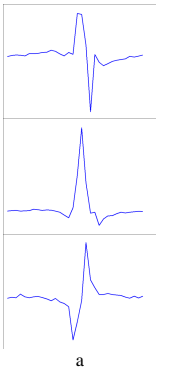


e

Fig.3 a. 2D PEPSI slice positioning. b. lipid image by integrating the lipid spectra. c and d. example spectra of pixels in lobular and ductal areas. e. lipid spectra within the rectangle area as marked in b.



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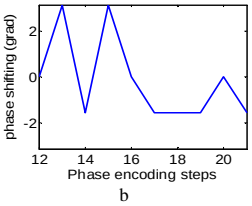

b

Fig.2 a. examples of navigator spectra of the imaging slice show the water frequency shift due to chest wall movement. b. measured phase shift across phase encoding steps.

suppressed 2D PEPSI data were acquired with slice thickness of 5mm, resulting in a voxel were acquired with TR/TE: 0.63s/11ms, resulting in a voxel size of 0.14 cc. Water- and 3s/75ms, 8 averages, 32x32 matrix, 320 mm Raw data were reconstructed as described sequence parameters and single average were current correction. Spectral quantification was integrated in LCModel.

RESULTS

Figure 2a shows slice-localized spectra reconstructed from the navigator data that show phase changes in the PEPSI slice between phase encoding steps due to chest wall movement. Figure 2b shows the measured phase change as a function of phase encoding step. Fig.3a shows an example of slice positioning for 2D PEPSI. Fig.3b shows the lipid image which is calculated by integrating the area under the lipid peak. This image clearly shows the high concentration of lipid in the adipose tissues on the outside of the breast, and relatively low concentration in the central cone of fibroglandular tissue. Fig.3c and d show example spectra from fibroglandular area without lipids and from peripheral area with lipid (marked as pixel A and B in Fig.3b). Fig.3e shows a spectral array from the rectangle shown in Fig.3b. Fig.4a shows the positioning of 3D PEPSI with 8 slice encoding. The lipid image from the 2nd to the 7th slice are shown in Fig.4b. Spectral quality was comparable to the 2D case. Fig.5 shows an example of a water and lipid suppressed spectrum in a fibroglandular area acquired with 2D PEPSI in 12.5 min with superimposed LCModel fit. Identification of the Choline resonance in these data is challenging due to line broadening (FWHM < 0.05 ppm) and low SNR.

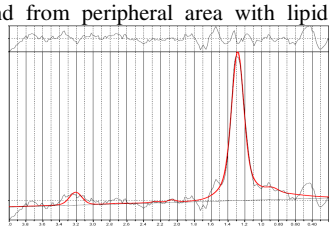

Fig.5 example of LCModel fit of water suppressed spectrum.

DISCUSSION

Preliminary data acquired without water and lipid suppression demonstrate high-speed MRSI of water and lipids in the healthy breast with excellent spectral quality and localization. Elevated lipids are possible markers of breast cancer and mapping the lipid distribution may provide complementary information for tumor characterization in dense tissue regions where detection of the extent and multifocality of tumor tissue on standard mammograms is challenging. Water suppressed data show acceptable spectral quality. However, Choline mapping was not yet feasible due to insufficient SNR as a result of small voxel size, shimming limitations across the PEPSI slice and lipid bleeding from adjacent voxels. These limitations are currently being addressed using localized shimming in the regions of interest and spatial suppression of lipid containing regions.

REFERENCES:. [1] Bolan, P. et. al. MRM 50:1134–1143, 2003. [2] Jacobs, M., et. al.. JMR, 21:23–28, 2005. [3] Posse, S., et. al., Radiology 192:733-738, 1994.[4] Posse, S., et al., Magn. Recon. Med. (2007), Vol 58, (2), 236 - 244 [5] M. Mescher, 1998 11: 266 – 272. [6] Meisamy S. et al., Radiology 236:465-475, 2005

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