

Proton Chemical Shift Imaging for Characterization of Heterogeneous Human Breast Tumors

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Introduction

Previous studies have shown that proton magnetic resonance spectroscopy (¹H-MRS) can be used to aid in diagnosis of breast lesions as well as to monitor early treatment response [1-2]. Most earlier studies have employed the single-voxel technique. However, breast cancer is known to exhibit morphological and metabolic heterogeneity, not only within the entire lesion but also the surrounding breast tissues. The chemical-shift imaging (CSI) is a useful technique for analyzing the regional heterogeneity of tumor metabolites. Recently several studies suggested the potential of this technique for diagnosis of breast lesions [3]. Since a smaller voxel size can be achieved in CSI compared to the single-voxel technique, it should be more useful for characterizing small lesions. Most CSI studies are performed at high fields; further investigations are needed to determine whether the CSI is also applicable on a clinical 1.5T scanner. In this study we applied high-resolution 2D-CSI technique to measure the spatial heterogeneity of choline-containing compounds (Cho) in malignant and benign breast lesions, to demonstrate the feasibility of this technique for characterizing breast tumors at 1.5T within an acceptable scan time.

Methods

Twenty patients with breast tumors were included in this study. The examinations were performed on a Philips Eclipse 1.5 T MR system with the dedicated bilateral breast coil. Dynamic contrast enhanced MRI was first performed, then 2D-CSI was acquired using a point-resolved spectroscopic (PRESS) sequence. The CSI grid was carefully positioned to maximize coverage of the hypointense lesion and minimize the inclusion of adipose tissue using the sagittal pre-contrast images. The PRESS spectral parameters were TR/TE = 1627/270 msec, matrix size = 8 × 8, FOV = 8 cm, and sagittal section thickness = 12mm. Four acquisitions were taken, with a total data acquisition time approximately 8 minutes. The echo signal was digitized with 2048 data points and a spectral width of 2040 Hz. The suppression of water was accomplished with three chemical shift selective (CHESS) RF pulses with a bandwidth of 64 Hz, and fat signal was independently attenuated by using inversion recovery (STIR)-based fat signal nulling. The spectroscopic data were zero-filled to 4096 data points then processed by Fourier transformation, with a Hamming filter in the spatial (phase-encoding) domains, Gaussian line broadening of 1.5 Hz, and a high-pass filter to reduce the residual water signal in the time domain. The Cho peak was resolved at 3.20 ppm. Within each voxel, the peak area was obtained by employing the Levenberg-Marquardt algorithm to fit the Gaussian to Lorentzian type. The peak height of Cho was measured and calculated with respect to the background noise level between 7.0 and 9.0 ppm as the Cho signal-to-noise ratio (SNR).

Results

Sixteen patients had breast carcinomas and four had benign lesions (2 fibroadenoma, 1 chronic inflammation, and 1 fibrocystic changes). In all patients, the suspicious breast lesions were enhanced in dynamic contrast enhanced MR imaging. The mean size of carcinomas was 5.2 cm (range 2.5 - 9.4 cm) measured as the largest tumor diameter from the axial subtraction images. The size of enhanced tissue areas in 4 benign cases ranged from 1.2 - 6.4 cm. In 15 of 16 patients with carcinomas, elevated Cho peak was clearly detected. The averaged Cho SNR were 5.2 ± 3.7 (mean \pm SD, n = 15) in patient with malignant tumors. This result was reasonably consistent with the previously published value (i.e., 6.2 ± 2.1 , Jacobs et al. [3]). No Cho signals were detected in all 4 patients with benign lesions. Figure 1 shows examples of MR and 2D-CSI measurement from one patient with invasive lobular carcinoma, and another patient with invasive ductal carcinoma. Both lesions showed hypointensity on Sagittal pre-contrast images (A and C). The Cho metabolite map is overlaid to demonstrate the distribution within each lesion (B and D). Figure 2 shows the spectrum taken from the red spot area (2×2 voxels) of the second patient, demonstrating a high Cho SNR (12.1), suggesting high cellular proliferation.

Discussion

In this work a multi-voxel 2D-CSI technique with 1.0 × 1.0 × 1.0 (or 1.2)-cm voxel size was applied to measure the Cho metabolite map at 1.5T. The results demonstrated the feasibility of this technique to characterize malignant breast lesions. None of the benign cases showed a Cho signal. Because of its small voxel size and the ability to analyze the metabolic heterogeneity, 2D-CSI is superior to the single-voxel spectroscopy technique. Additionally, the imaging time of 8 minutes is well acceptable. Therefore, we conclude that the use of CSI technique for a clinical 1.5T study might be of value for further characterization of DCE-MRI enhanced lesions to improve specificity. Such a technique may be helpful for pre-surgical treatment planning and post-treatment follow-up.

References 1. Yeung et al. Radiology 220:40-60 (2001). 2. Huang et al. Radiology 232:585-591 (2004). 3. Jacobs et al. JMRI 19(1):68-75 (2004).

Acknowledgement

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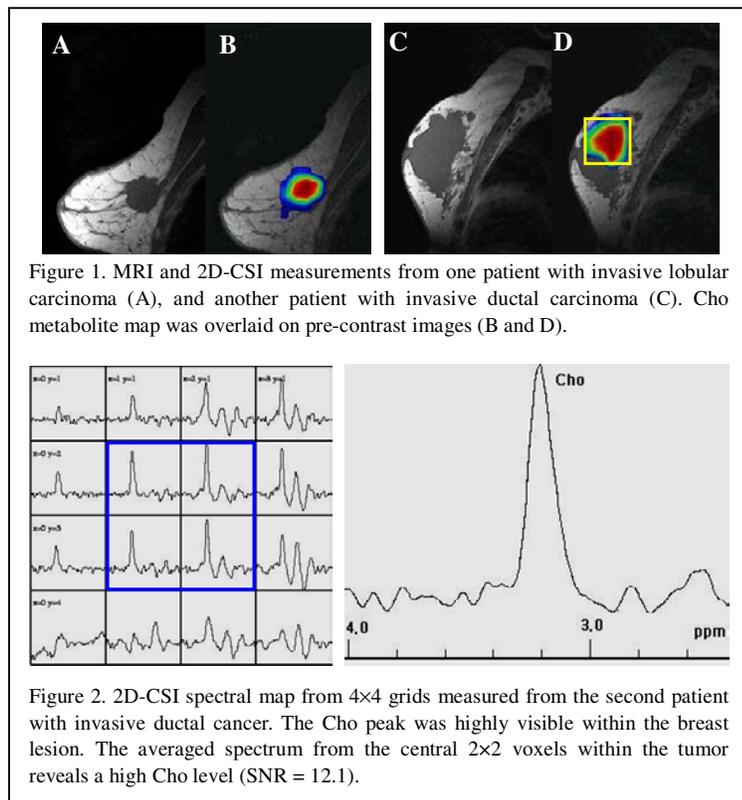


Figure 1. MRI and 2D-CSI measurements from one patient with invasive lobular carcinoma (A), and another patient with invasive ductal carcinoma (C). Cho metabolite map was overlaid on pre-contrast images (B and D).

Figure 2. 2D-CSI spectral map from 4x4 grids measured from the second patient with invasive ductal cancer. The Cho peak was highly visible within the breast lesion. The averaged spectrum from the central 2x2 voxels within the tumor reveals a high Cho level (SNR = 12.1).