A high spatial resolution 1H magnetic resonance spectroscopic imaging technique for breast cancer with a short echo time

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Introduction: High sensitivity but low specificity of breast MRI has stimulated breast 1H MRS. It has been well-documented that choline (Cho) helps distinguish malignant breast cancer from benign lesions. Despite significant progress, several obstacles still prevent the routine application of *in vivo* breast 1H MRS, including poor spatial resolution, long acquisition time associated with conventional multi-voxel MRS imaging (MRSI) techniques, the requirement of "extra" lipid suppression and relatively poor achievable magnetic field homogeneity compared to the brain (1). We hypothesize that the combination of recently developed echo-filter suppression technique and the elliptical sampling scheme can overcome these difficulties (2,3). In this report, we present our initial experience with *in vivo* high spatial resolution 1H MRSI of human breast lesions at a short echo time using the proposed technique.

Methods: The technique consists of three parts: optional inversion recovery, optional outer volume pre-saturation (OVP), and an echo-filter MRSI with a weighted k-space sampling scheme (3). The simplest echo-filter pulse sequence consists of a 90^0 RF pulse (or a series of pulses) to define the volume of interest (VOI), a delay TE/2, a frequency-selective (FS) 180^0 pulse, and another delay TE/2 with equally strong crusher gradients (G) on each side of the FS pulse (2). Undesired water and lipid signals are suppressed in two ways: 1) passively, by virtue of their position outside the frequency range of the 180˚ FS pulse, and 2) actively, by the gradients that destroy the phase coherence of any residual undesired signals due to the imperfections of the FS pulse. This "double" suppression mechanism ensures sufficient suppression of undesired signal frequencies with a properly designed FS pulse and gradient strengths. The OVP is determined by applying slice-excitation pulses to select the area outside the volume of interest (VOI), and can be turned on or off as needed. If necessary, lipids can be further suppressed with an inversion recovery method, particularly for those near the desired Cho signals. To improve sampling efficiency, a weighted k-space sampling scheme is used to acquire the MRSI data set (3).

Results: To date, six studies from five patients with DCE-MRI demonstrated breast lesions have been performed with the proposed technique on Siemens whole-body 1.5T. All but one were technically successful; one study failed before adding the inversion recovery option. Figure 1A (on the left) and 2A (on the right) show the spectra from biopsy proven tumor and control voxels respectively, with a TE of only 60 ms at 1.5T. The spatial resolution here is only 0.59 cm^3, the highest spatial resolution for *in vivo* 1H breast MRS at 1.5T to date. Other parameters are: TR= 1600 ms, Ave=8, acquisition time= 12.1 min, and a 60 Hz guassian FS pulse setting at Cho resonance (3.2 ppm). Excellent lipid and water suppression for *in vivo* 1H MRS was achieved, even though the magnetic field for the control voxel is relatively inhomogeneous as indicated by a much broader residual water peak in Fig 2A than in Fig 1A. Aside from 8 Hz filter in the time domain and fast Fourier transform (FFT), no other processing was used to generate the spectra.

Discussion: As demonstrated, the proposed technique has the potential to overcome the difficulties for routine breast 1H MRS. First, it is robust: the echo-filter suppression technique is insensitive to magnetic field inhomogeneity as long as the desired Cho signal (at 3.2 ppm) is spectrally separated from undesired signals (such as water at 4.75 ppm and lipid around 1.45 ppm). Second, the technique capitalizes on the fact that Cho is the only metabolite of interest in breast cancer to ensure efficient suppression of strong water and often stronger lipid signals. Third, spectral separation increases linearly with strength of the magnetic field, thus is less technically demanding at a high field than at a 1.5 Tesla. Fourth, spatial resolution can be further improved to 0.3 cm^3 at 3T with less technical difficulty or even shorter TE. Fifth, the desired Cho signals will be modulated by less than 2.5% if the FS excitation profile is designed to vary within 10% of the desired 180^0 excitation angle over the range of frequency of interest (*i.e.* $162^0 < \alpha < 198^0$) (data not shown). Sixth, it is fast, only adding about 15 minutes to an existing breast MRI protocol. Trade-offs are 1) the TE is restricted by the duration of the FS pulse, and 2) sometimes it is difficult to determine the internal reference peak due to the elimination of the water signal or its chemical shifting.

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Reference: (1) Jacobs MA, etc, JMRI , 19, 68(2004); (2) Wei C, etc, JMR, 140, 363(1999); (3) Maudsley A, etc, MRM, 31, 645(1994).

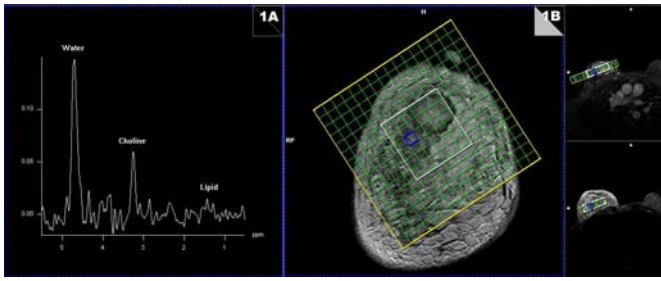

Figure 1: 1H spectrum from breast cancer.

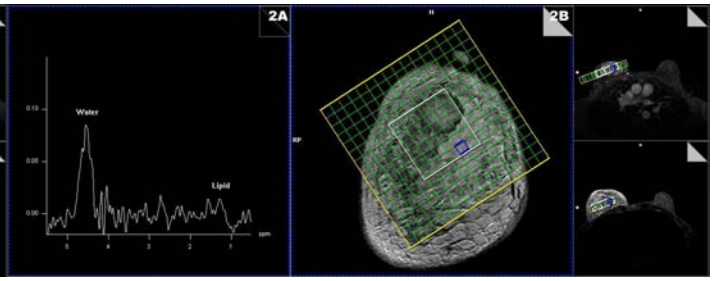

Figure 2: 1H spectrum from the control voxel.