A Customized Quadrature Transmit/Receive Breast Coil for Selective Multiple-Quantum (Sel-MQC) Spectroscopic Imaging of Breast Cancer Lactate on a 3T Clinical MR System

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INTRODUCTION. The tissue proton spectra of most extracranial organs are usually dominated by intense water and lipid resonances that block observation of metabolites and drugs. The breast tissues represent the worst-case scenario for the ^{1}H MRS observation of metabolites and drugs.[1] Roebuck *et. al.* have demonstrated the feasibility of ^{1}H MRS of breast cancer with choline detection using the spin-echo techniques.[2] *In vivo* clinical observation of lactate, however, has been challenging in breast and other extracranial cancers. To overcome these obstacles, we have developed the Selective Multiple-Quantum Coherence transfer (Sel-MQC) methods that completely suppress lipid and water in a single scan, for observing metabolites and antineoplastic agents in tissues containing high concentration of mobile fat.[3-6] These methods have been demonstrated for simultaneous lactate and choline detection in EMT6 tumors[4] and for Iproplatin detection in RIF-1 tumors.[5] A multi-slice Sel-MQC method has been developed for 3D Sel-MQC mapping of metabolites using a Hadamard Matrix approach.[7] The Sel-MQC techniques with spectral-volume selectivity[8] and the T_1- and T_2-SelMQC sequences to determine relaxation times of the edited lactate signals have also been developed.[9] Modified Sel-MQC sequences are available to detect neuronal metabolites glucose, GABA and glutamate with reduced signal overlap and excellent water suppression.[10,11] The preliminary studies of human breast cancer have been carried out on a 2.1T research magnet, indicating that the high-field magnet will improve the effectiveness of lipid suppression. The Sel-MQC sequence is sensitive to B_1 inhomogeneity and therefore, a breast coil with homogeneous RF field is critical for tissue metabolite detection. In this report, we present a successful implementation of the Sel-MQC methods on a GE 3T clinical scanner and lactate mapping using a quadrature breast coil with excellent B_1-homogeneity and signal-to-noise (S/N) ratio.

METHODS. ***Sel-MQC:*** The chemical shift imaging version of the Sel-MQC pulse sequence, $90^0_{\phi}(C\underline{H}_3, lipid)$ -1/2J- $90^0_x(C\underline{H}, \underline{H}_2O)$ -t_1/2,g_1- $180^0_x(C\underline{H}_3, lipid)$ -$t_1/2, g_2$ - $90^0_x(C\underline{H}, \underline{H}_2O)$ - $g_3, \tau \pm t_1$ - acq, was implemented on the GE Signa 3T scanner. Frequency selective 90^0 pulses of duration 11.7 ms were applied to excite only lactate into the MQ-states. The signals of lipid and water remain in the SQ modes, completely suppressed by the three magnetic field gradient pulses (g_1: g_2: g_3 =0:-1:2 or 1:0:2) that serve as a MQ-coherence filter for lactate selection.

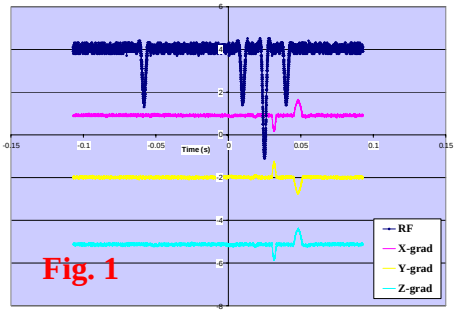

Fig. 1

Breast Coil: A quasi-quadrature transmit/receive breast coil in a modified bird cage configuration of 8 parallel elements was employed.[12] One of the elements was replaced by two new elements that form a circular opening to allow breast entry into the coil cavity. The two-ends of the modified bird cage had reduced radii to retain most of the RF field inside the resonant cavity. This design gives excellent MRI images of human breast tissues with good B_1-field homogeneity.[12] The S/N ratio of the quadrature breast coil on our GE 3T MR system was measured to be 500.

Phantoms: To test the B_1 inhomogeneity effect of the coil on the Sel-MQC performance, we constructed a two-compartment Lac/H_2O phantom with two concentric spheres. The inner sphere (O.D. = 6 cm) contained a 20 mM lactate aqueous solution, and the outer compartment (O.D. = 8.6 cm) contained saline. To demonstrate the effectiveness of lipid suppression, a second phantom (Lac/H_2O/Oil) was constructed by attaching two test tubes filled with vegetable oil to the first phantom.

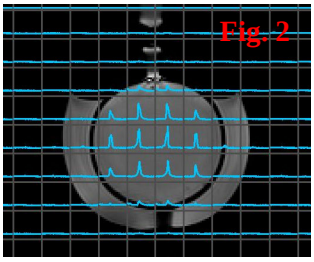
Fig. 2

RESULTS. The Sel-MQC sequence was implemented on the 3T GE Signa LX VH3 clinical scanner in the University of Pittsburgh MR Research Center. The CSI map of lactate from the Lac/H_2O phantom confirms the excellent B_1-field homogeneity of the quadrature coil for the Sel-MQC experiment (Fig. 2). The entire sample was included in the slice-selective dimension to search for any poor image areas generated by inhomogeneous B_1- or B_0-fields. In all experiments, only linear shims were optimized during the scanner "AutoScan" procedures. The lactate editing with the Lac/H_2O/Oil phantom was performed using a 3 ms DQ-gradient (Max. 4 G/cm) to select the ZQ→DQ pathway (Fig. 3). A trace of residual lipid remaining as a broad line can be removed by improved shimming.

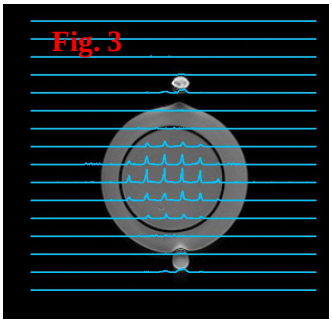
Fig. 3

CONCLUSIONS. The quadrature breast coil using a modified birdcage configuration gives excellent B_1-homogeneity and S/N ratio for spectroscopic imaging of lactate using the Sel-MQC method on the GE 3T MR scanner. This prototype coil construction will be further improved for high-field 3T and 7T MR spectroscopy and imaging of human breast cancer.

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REFERENCES: (1) Sijens, P. E., et al, *Radiology* **1988** *169*, 615-20. (2) Roebuck, J. R., et al, *Radiology* **1998** *209*, 269-275. (3) He, Q., et al, *J. Magn. Reson. B* **1995** *106*, 203-211. (4) He, Q., et al, *J. magn. Reson., Series B* **1996** *111*, 18-25. (5) He, Q., et al, *Magn. Reson. Med.* **1994** *33*, 414-416. (6) Bhujwalla, Z. M., et al, In *NMR in Physiology and Biomedicine*; R. J. Gillies, Ed.; Academic Press: San Diego, 1994; pp 311-28. (7) He, Q.; et al, *Proc. Intl. Soc. Mag. Reson. Med.* **1997** ***3***, 1447. (8) Thakur, S. B.; He, Q., *Proc. Intl. Soc. Mag. Reson. Med.* **2003.** (9) Murugandham, M., et al, *Magn. Reson. Med.* **2003** (Accepted). (10) De Graaf, R. A., et al, *Magn. Reson. Med.* **2000** *43*, 621-6. (11) Shungu, D. C., et al, *Proc. Intl. Soc. Mag. Reson. Med.* **2003** *11*, 1140. (12) Mao, J.; Ballinger, J. R., *Proc. Intl. Soc. Mag. Reson. Med.* **1998** *1*, 642.