Preliminary Experience with Breast ^{1}H MRS at 7 Tesla

P. J. Bolan[1], C. J. Snyder[1], L. J. DelaBarre[1], L. Bolinger[2], M. Garwood[1], J. T. Vaughan[1]

[1]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States, [2]Institute for Biodiagnostics, National Research Council Canada, Winnipeg, Manitoba, Canada

Introduction: Measurement of total choline-containing compounds (tCho) by localized ^{1}H MRS offers a means to distinguish malignant from benign lesions (*1*) and to predict response to neoadjuvant chemotherapy (*2*). The detection of tCho in small lesions having low cellularity is usually limited by insufficient SNR at clinical field strengths. Furthermore, the only metabolite routinely detected in breast cancers is tCho, despite the fact that many metabolites are observable in high field ^{1}H spectra of extracts (*3*). Previous breast MRS studies at 4 T have reported higher SNR, enabling the detection of tCho in smaller lesions as well as the occasional detection of other metabolites such as taurine, creatine, and glycine (*4*). The purpose of this work was to investigate the feasibility of performing localized ^{1}H MRS of breast at 7 T, with the hypothesis that high SNR and spectral resolution would further improve the detectability of tCho and other metabolites *in vivo*.

Methods: MRI and MRS data were acquired from five normal female volunteers on a whole-body 7 T magnet (Magnex Scientific, Oxfordshire, UK) equipped with a Sonata gradient system (Siemens, Erlangen, Germany) and interfaced with a Unity Inova spectrometer (Varian, Palo Alto, USA). A circularly-polarized, unilateral RF coil consisting of two shielded crossed loops driven in quadrature was used for transmission and reception (Fig. 1), similar to a previous 4 T design (*5*). To distinguish adipose from fibroglandular tissue, T_1-weighted images were acquired using fat-suppressed 3D FLASH. Single-voxel spectra were collected using the LASER pulse sequence (*6*) and TE averaging (*7*). Quantification of fibroglandular tCho used the (unsuppressed) water signal in the voxel as an internal reference (*4*). T_1 and T_2 relaxation times of water and lipid resonances were measured in fibroglandular and adipose voxels using variable inversion recovery times (TI) and echo delays (TE), respectively. Respiration-induced frequency variations were measured and corrected by saving individual FIDs prior to averaging, as described previously (*8*).

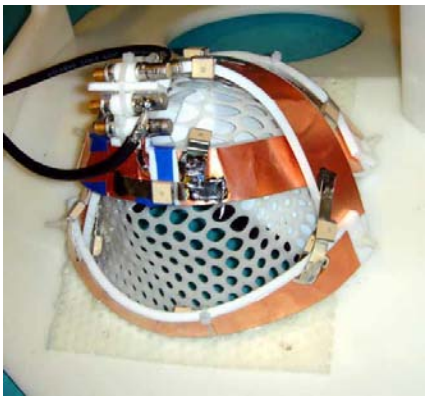

Figure 1 – Image of the unilateral breast coil mounted a dual-breast platform.

Results: In 7 T studies of all subjects, excellent fat suppression in images was easily achieved due to the large frequency separation between fat and water signals. While the image quality and contrast was excellent in the anterior portion of the breast, the coil sensitivity dropped off steeply near the chest wall (Fig. 2). After imaging, one or two MRS voxels were placed in normal-appearing fibroglandular tissue of each subject, ranging from 1.7-15.6 mL in size. Manual adjustment of linear and second-order shims was required to produce sufficiently narrow linewidths (mean water linewidth = 23.5 Hz). Of the six spectra acquired, five displayed a tCho resonance at 3.2 ppm, and two showed a taurine resonance at 3.4 ppm (e.g., Fig 3). After processing and spectral fitting, four of the six spectra had a tCho resonance that met the detection criterion (normalized Cramer-Rao minimum variance bounds <= 100%). The mean estimated tCho concentration was 0.29 mmol/kg, with mean error of 0.08 mmol/kg. These quantities are consistent with prior experience at 4 T, which showed that tCho concentrations in normal subjects were typically < 0.5 mmol/kg (*4*). The respiration-induced frequency shifts over each scan varied an average of 39.6 Hz, which represents a linear increase in amplitude compared to the previously published value of 24 Hz at 4 T (*8*). Relaxation times for water and fat were measured in voxels from two different subjects: T_1(water) = 2265 ms, T_1 (fat) = 482 ms, T_2(water) = 35 ms, and T_2 (fat) = 74 ms.

Discussion: This study demonstrates the feasibility of performing breast MRI and MRS at 7 T. As expected, the crossed-loop quadrature coil design has reduced penetration compared to similar 4 T coils, indicating the need to develop new designs for ultra-high field breast coils. Magnetic susceptibility did not appear to limit the quality of the fat-suppressed MRI and ^{1}H spectra, although adjustment of linear and second-order shims was required for MRS. The ability to detect relatively narrow tCho and taurine resonances in normal breasts provides motivation to pursue future 7 T studies of breast cancer. The ability to detect *in vivo* alterations in taurine levels, as well as tCho, may contribute to the understanding of the aberrant metabolic properties of breast neoplasms.

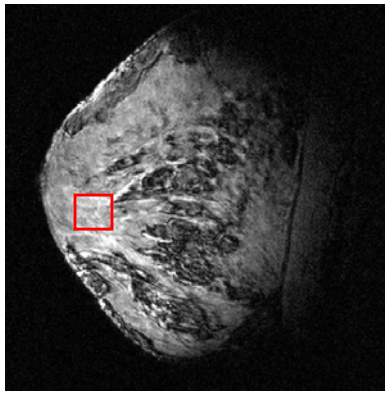

Figure 2 – Sagittal slice from a fat-suppressed, T_1-weighted 3D FLASH image (TR/TE = 15/5 ms, FOV 14cm, matrix 256x256x64) acquired in a normal subject. The box indicates the` placement of the voxel in the normal-appearing fibroglandular tissue.

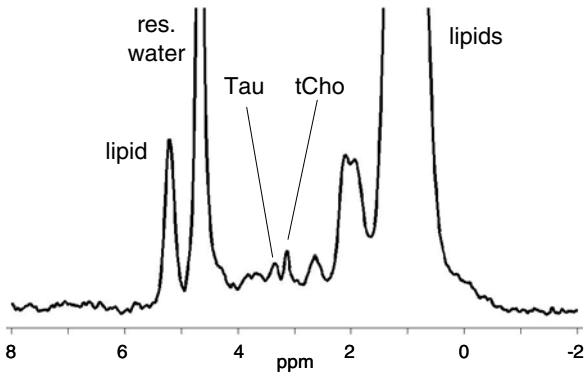

Figure 3 – Single voxel spectrum acquired from the voxel indicated in Fig. 2 (LASER localization, VOI=1.6mL, TR=3s, TE=43-195 in 128 increments, 8Hz line broadening). Clear peaks from taurine and tCho are visible even in this healthy subject.

References: 1) Katz-Brull R, et al., J Natl Cancer Inst 2002; 2) Meisamy S, et al., Radiology 2004; 3) Gribbestad I, et al., Anticancer Res 1999; 4) Bolan PJ, et al., MRM 2003; 5) Merkle H, et al., Proc 9th ISMRM 2001; 6) Garwood M and DelaBarre LJ, JMR 2001; 7) Bolan PJ, et al., MRM 2002; 8) Bolan PJ, et al., MRM 2004.

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