Breath-Hold Abdominal and Thoracic Proton Magnetic Resonance Spectroscopy at 3T

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Synopsis

This work demonstrates the feasibility of *in vivo* breath-hold body ^{1}H-MRS on a 3T scanner equipped with a torso multicoil array. Frame-to-frame phase and frequency shifts and voxel contamination (associated with respiratory motion) were eliminated or markedly reduced using breath-holding. Tumor free kidney tissue and metastases of renal cell carcinoma in the abdomen and thorax were investigated using a single or multiple breath-hold datasets. Spectra of the tumors showed a resonance at 3.2 ppm. The results suggest that biochemical characterization of abdominal and thoracic tumors may now be possible *in vivo*.

Methods

This work was performed as part of a larger study aimed at finding surrogate MR markers for response of renal cancer to an antiangiogenic treatment. Patients with renal cancer and metastases were recruited for this study through the Massachusetts General Hospital and Dana-Farber Cancer Institute. Informed consent was obtained in accordance with the guidelines of the institutional review boards of the Massachusetts General Hospital, Dana-Farber Cancer Institute, and Beth Israel Deaconess Medical Center.

The studies were performed on a 3T scanner (Signa LX, General Electric, Waukesha, WI) equipped with a body coil for RF transmitting and a torso phased array coil (4 coils) for receiving. Breathing instructions were explained to the patients before entering the magnet. Anatomical and functional images were acquired in a breath hold with a comprehensive imaging protocol, the results of which will be described elsewhere. The localizer image for the MRS voxel was selected from the anatomical images. Single voxel PRESS ^{1}H spectra were acquired with a repetition time of 2 sec, time to echo of 144 msec, spectral width of 5000 Hz, and 512 time points. MR Spectroscopy during breath-hold at end expiration was performed in 20 sec. This time frame allowed for 2 "dummy" scans and 8 acquisitions.

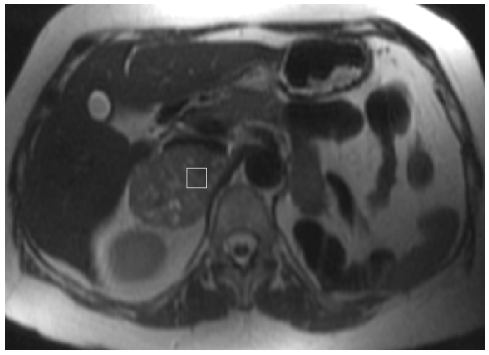
Results

The frame-to-frame phase and frequency shifts in abdominal and thoracic tissues, were typically high in spectra that were obtained during free breathings and extremely low in spectra that were obtained during breath-holds. These frame-to-frame phase and frequency shifts during breathing lead to a reduction in the SNR of the residual water in a summed spectrum of the individual scans. The frame-to-frame variations in phase and frequency were corrected in post-processing with an individual phase correction algorithm and frequency registration of the residual water-signal. Using these correction algorithms the sum of the water signal was similar in free breathing and breath-hold. Inspection of the lipid signal in the same spectra revealed a similar effect on the lipid signal that showed a similar phase and frequency in all frames. However the frame-to-frame intensity of the lipid signal was highly variable in magnitude during free breathing but reproducible during breath holding. These results suggested that signal losses due to phase and frequency shifts could be restored via correction algorithms, however, the contamination of the spectra by signals that arose from outside the region of interested could only be achieved by breath holding.

The utility of the multiple breath-hold summation approach is demonstrated in an example is of a renal cell carcinoma metastasis in the adrenal gland (Fig. 1). The spectrum obtained in a single breath-hold and the sum of four and eight breath-holds at this location are shown in Fig 1B-D. The large signal at 4.7 ppm is due to residual (partially suppressed) water. The signal at 3.2 ppm was assigned to the trimethylamine moiety (TMA) that is common to the choline containing compounds. The signal at ~1.3 ppm was assigned to the methyl moieties of fatty acids (lipids). Individual breath-hold data were summed in post processing.

Discussion

By combining high field strength and localized multicoil array for abdominal and thoracic proton MRS, cumulative improvements in SNR were achieved while breath holding minimized both inadvertent sampling of tissues outside the region of interest and phase and frequency variations. Retrospective summation allows increased acquisition times without introducing motion artifacts. We have utilized this approach following the successful application of this method in MR imaging (1). Obviously, however, the patients ability to perform a breath-hold must be considered when implementing or modifying an imaging/spectroscopy protocol for a particular patient. Previous studies of proton MRS of the abdomen (2-5) (and references cited therein) were performed at 1.5T. The clinical utility of *in vivo* proton MRS in characterizing the nature of tumors (benign vs. malignant) and in predicting the effectiveness of cancer treatment has been well demonstrated in tumors of the brain, breast, and prostate. Specifically, an increased level of the "composite choline" signal (at 3.2 ppm, predominantly due to TMA moieties of choline metabolites as well as ethanolamine and taurine) with respect to normal surrounding tissue has been shown to be indicative of malignancy (6 and references cited therein). Our preliminary experience with renal cancer and its metastases suggest that these tumors contain higher levels of "composite choline" than their tissue of origin, the kidney. The potential of proton MRS as a diagnosing tool for renal and lung cancer has been recently reviewed (7-9). Analysis of in vitro high resolution spectra of specimens removed during surgery showed promise for identifying biochemical profiles characteristic of benign and malignant tumors of different grades. The results of the current work suggest that characterization of renal and lung tumors using proton MRS may now be carried out *in vivo*.



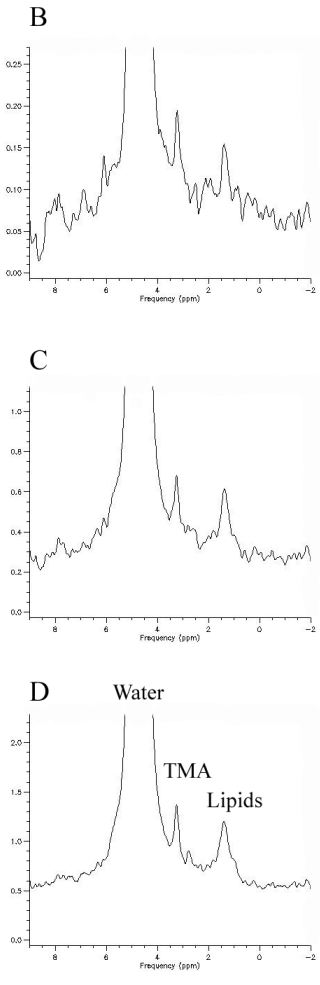


Figure 1: A. A single shot fast spin echo image of the abdomen recorded in a breath-hold at end expiration. A large renal cell carcinoma metastasis in the right adrenal gland is demonstrated. The MRS voxel (square in white, 2 x 2 x 2 cm^3) was localized in the center of the tumor.
B), C), and D) The proton spectrum at the location demonstrated in A acquired with 1, 4, and 8 breath-holds, respectively. The total scan time for eight breath-holds was 2.1 min. The large signal at 4.7 ppm is due to partially suppressed water. The signal at 3.2 ppm was assigned to the trimethylamine moiety (TMA) that is common to the choline containing compounds. The signal at ~1.3 ppm was assigned to lipids. Breath-hold data were summed in post processing.

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References

1. Feinberg DA et al. Magn Reson Med 1995;34:905-909. 2. Star-Lack JM et al. Magn Reson Med 2000;43:325-330. 3. Tyszka JM et al. Magn Reson Med 1998;39:1-5. 4. Dixon RM et al. Magn Reson Med 1994;31:482-487. 5. Cho SG et al. Radiology 2001;221:740-746. 6. Katz-Brull R et al. J Natl Cancer Inst 2002;94:1197-1203. 7. Nurenberg P et al. Curr Opin Urol 2002;12:375-380. 8. Tosi MR et al. Int J Mol Med 2002;9:299-310. 9. Hanaoka H et al. Magn Reson Med 1993;29:436-440.