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 1H-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 localization image for the MRS voxel was selected from the anatomical images. Single voxel PRESS ¹H 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 the residual water-signal was assigned to lipids. 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 patient’s ability to perform a breath-hold must be considered when implementing or modifying an imaging/spectroscopy protocol for a particular patient.

The results suggest 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 interest could only be achieved by breath holding.

The utility of the multiple breath-hold summation approach is demonstrated in an example 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.

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 cm³) 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 TMA signal 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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