In Vivo Proton MR Spectroscopy of Thyroid Tumors: Towards Non-Invasive Management

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Introduction:
Cytology of biopsies obtained through fine-needle aspiration (FNA), the standard diagnostic modality for thyroid cancer, is unable to discriminate benign from malignant follicular thyroid nodules, which are differentiated only by capsular or vascular invasion. Therefore, many thyroidectomies are performed simply to exclude a diagnosis of malignancy. In the benign case, the thyroid gland is unnecessarily removed solely for diagnostic purposes. Ex vivo proton MRS on resected tissue as well as on FNA has been reported to accurately discriminate malignant thyroid nodules from normal tissue1,2. The ability to localize and non-subjective diagnosis and may aid in the clinical management of thyroid nodules.

The thyroid gland lies about 2 cm below the surface of the neck. Therefore, a small surface coil rather than a volume coil can be used to maximize the signal-to-noise ratio (SNR). In addition to respiratory/circulatory motion-related problems, the location of the thyroid being next to the trachea creates a large B0 inhomogeneity and hence poor spectral line widths.

We describe herein 1H MRS methods at 3T to address many of these problems. We also compare our 3T results to standard techniques at 1.5T.

Methods:
RF Coil and Pulse Sequence: To obtain improved STEAM localization and uniform sensitivity across the voxel, a multi-ring surface coil was used in place of the standard single loop surface coil3.

Slice Selection Order: Spectral artifacts created by unwanted coherences in STEAM localization were minimized by choosing the optimal order of the three slice-selection gradients4.

Shimming: To improve B0 homogeneity, FASTMAP5 automatic localized shimming was implemented to correct all 1st and 2nd order shims. To overcome discontinuities in phase projections, a variable fitting range and weighted polynomial regression were used to calculate spherical harmonic coefficients of the measured B0.

Motion Correction: To correct for line broadening from respiration, individual FID’s were collected separately, then automatically frequency and phase shifted on a metabolite peak before averaging.

Data Acquisition:
Localized proton MR spectra were obtained from the thyroid of normal volunteers (N=30) and patients (N=4) with a thyroid nodule on a Bruker/Magnex 3T, whole-body MR scanner using a multi-ring surface coil and STEAM localization (TR=2000ms, TE=20ms, TM=15ms, Prescans=4, Averages=128). Normal breathing was maintained during acquisition. For comparison, localized STEAM thyroid spectra were also obtained on a Siemens SP 1.5T whole body scanner from normal volunteers (N=20) using both a standard 5-cm surface coil and a Helmholtz style volume coil. Images were obtained with FLASH (TR = 170ms, TE = 8ms, thickness = 5 mm).

Results:
In vivo thyroid spectra obtained using the proposed 3T method (Fig. 2), including individual frequency and phase adjustments to correct for respiratory motion artifact, are much improved over typical 1.5T results (Fig. 1) using the standard techniques of manual linear shimming without motion correction. Optimized slice selection order was important in some subjects where significant spectral artifacts were apparent. Spectra obtained from thyroid tumors larger than 2-cm benefit greatly from automatic local shimming (Fig. 3).

Conclusions:
We have demonstrated a method to produce high quality 1H MR spectra of thyroid tumors in vivo. Considerable improvement in SNR and resolution is apparent at 3T compared to 1.5T. Optimizing the slice-selection order as well as automatic localized shimming and frequency/phase correction may be necessary for achieving optimal spectral resolution. The combined use of STEAM localization and a multi-ring surface coil offers the SNR advantages of a surface coil with excellent localization suitable for obtaining quantitatively accurate spectra and, therefore, may make it possible to manage thyroid tumors non-invasively.

References:

Fig. 1 In vivo 1H spectra from a normal thyroid gland at 1.5T using (a) a Helmholtz neck coil and (b) a 5-cm standard surface coil.

Fig. 2 In vivo 1H spectra from a normal thyroid gland at 3T (a) without and (b) with frequency/phase correction.

Fig. 3 (a) Axial image and (b) corresponding in vivo 1H spectrum from a follicular nodule at 3T.