

Reduction of Endorectal Surface Coil Artifact in 1H Spectroscopic MRI of Prostate Cancer

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Introduction

¹H MR spectroscopic imaging (MRSI) has become an important tool for the evaluation and staging of prostate cancer patients since changes in the peak areas of the choline, polyamines, and citrate resonances have been correlated with the presence and aggressiveness of prostate cancer [1]. However, the inhomogeneous reception profile of the endorectal coil reduces metabolite peak areas with distance from the coil, confounding the interpretation of the prostate MRSI data. The diminished coil sensitivity in the anterior aspect of the prostate can cause central gland tumors to be missed on ¹H MRSI. Typically the choline/citrate or (choline+creatinine) / citrate metabolite peak area ratios are used to identify cancer and to address the inhomogeneous reception profile [2,3]. However, these ratios can be quite variable, particularly when citrate levels are low, as in cancer and in the central gland. The elevation of choline levels alone may be a more robust indicator of cancer presence and cancer aggressiveness [3]. To overcome the problems with metabolite ratios and provide the ability to monitor individual metabolites, we have developed a semi-automatic procedure which normalizes the MRSI data to the analytic reception profile of the endorectal coil [4]. The aim of this study was to 1) evaluate the improvement in spectral homogeneity in phantoms and patients using this coil correction algorithm and, 2) in an additional group of patients with central gland tumors, determine the tumor choline versus healthy peripheral zone choline before and after coil correction to illustrate the potential of this method to facilitate central gland tumor detection.

Methods

The endorectal receiver coil's sensitivity map was modeled based upon the Biot-Savart Law [4]. The coil's position and orientation were manually identified on the axial and sagittal T2-weighted images. The field map was rotated, translated, and sinc-resampled to the resolution of the MRSI data. The spectral array was then normalized by the resampled coil profile. Numerical integration of suppressed water, choline, creatine, and citrate was performed before and after coil correction using the known frequency positions of each of these peaks [5].

Three uniform phantoms and 18 prostate cancer patients were scanned at 3T using PRESS selected, 3D (12x16x16) MRSI with TR/TE=1300/85 and 0.16cc resolution. In the 3 phantom studies, the average coefficients of variation $c_v = \sigma/\mu$ for integrals of the water, choline, creatine, and citrate peaks for all non-VSS-suppressed voxels in the selected volume were calculated before and after correction. For the patients, c_v was only calculated for water, due to large biological variability in metabolites. In three patients, the choline peak areas were analyzed in anterior prostatic regions that were suspicious of tumor by lowered apparent diffusion coefficient (ADC) [6]. ROIs were drawn around the regions of ADC abnormality and regions of healthy peripheral zone. The ratio of the mean choline integral value in the tumor region to that in the healthy region was then calculated for both the corrected and uncorrected choline maps.

Results

All peaks from the phantom scans showed increased uniformity with lower c_v values post-correction (see Table 1). Figure 1 shows this improvement in the spectral data facilitating the visualization of spectra especially anteriorly. Figure 2 graphically shows this improvement as increased flatness in the axial profile of the phantom citrate integrals post correction. Uniformity of water also increased in the 18 patients (c_v pre = 1.0 ± 0.2 to c_v post = 0.7 ± 0.1 , $p < 0.05$).

As shown in Figure 3, correction of spectra for the reception profile of the endorectal coil improved detection of the anterior tumor based on elevated choline. The patient in Figure 3 had a biopsy proven anterior central gland tumor which was not clear on T2-weighted images (Figure 3a), the (choline+creatinine)/citrate map (Figure 3b), or the uncorrected choline map (Figure 3c), but was clear on the corrected choline map (Figure 3d) and on the apparent diffusion coefficient (ADC) map (Figure 3e). For the three cases with central gland tumors, the ratio of choline integrals within the abnormal regions to the integrals in the healthy peripheral zone increased from 1.0 ± 0.2 ($\mu \pm \sigma$), or no difference, for uncorrected spectra to 2.0 ± 0.9 ($\mu \pm \sigma$) for corrected spectra.

Discussion

This correction algorithm not only decreases variability in metabolite levels, it also shows promise in facilitating cancer detection and, ultimately, in facilitating automated spectral classification. The absolute peak areas of coil-corrected data could yield automatically produced maps that are more sensitive and more specific to pathology than uncorrected maps or metabolite ratio maps, which become quite variable when the divisor metabolite has low signal to noise. The elevated choline voxels indicating a central gland tumor in the post-correction choline map in Figure 3d) are clearly more specific than the pre-correction map (Figure 3c). The evaluation of absolute peak area maps generated in this fashion may enable more objective and automatic spectral interpretation.

References

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Table 1: Increase in phantom metabolite area uniformity with MRSI coil correction.

Peak	c_v before*	c_v after**	Improvement
Water	$0.7 \pm 0.1^{**}$	$0.4 \pm 0.1^{**}$	$39 \pm 8\%$
Choline	$0.8 \pm 0.1^{**}$	$0.6 \pm 0.1^{**}$	$23 \pm 5\%$
Creatine	$0.8 \pm 0.2^{**}$	$0.7 \pm 0.2^{**}$	$14 \pm 5\%$
Citrate	0.6 ± 0.1	0.4 ± 0.2	$30 \pm 20\%$

* average value of three scans using an average of 1250 PRESS-selected voxels, ** $p < 0.05$, paired t-test

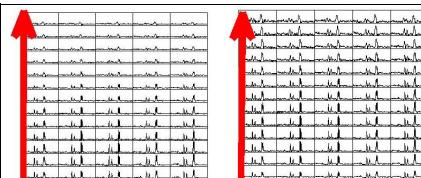


Figure 1a: Uncorrected phantom spectra (arrow shows increasing distance from coil) Figure 1b: Corrected phantom spectra showing more homogeneous peak sizes

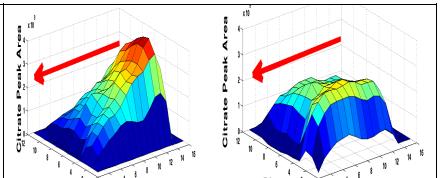


Figure 2a: Phantom citrate integrals diminish with distance from the coil. Figure 2b: Post-correction citrate exhibits relatively flat profile

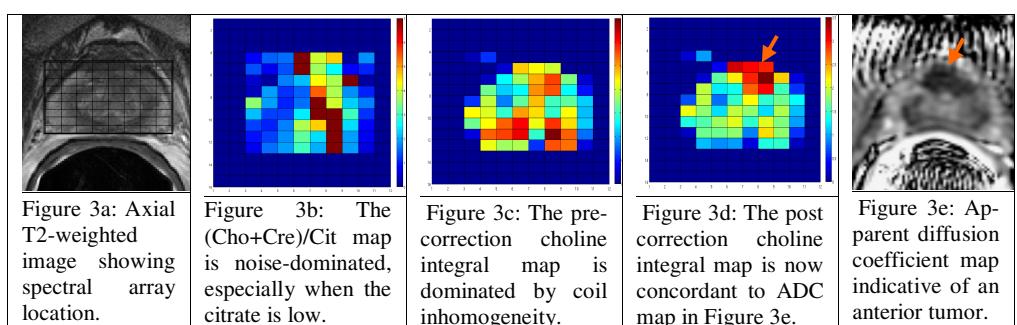


Figure 3a: Axial T2-weighted image showing spectral array location.

Figure 3b: The (Cho+Cre)/Cit map is noise-dominated, especially when the citrate is low.

Figure 3c: The pre-correction choline integral map is dominated by coil inhomogeneity.

Figure 3d: The post correction choline integral map is now concordant to ADC map in Figure 3e.

Figure 3e: Apparent diffusion coefficient map indicative of an anterior tumor.