In Vivo Sodium Imaging of Human Prostate Cancer

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Target Audience: Scientists developing MRI methods for prostate cancer detection and sodium imaging

PURPOSE: One in seven men will develop prostate cancer (PCa) in their lifetime. While the age-standardized relative survival ratio is 95%, men who are diagnosed experience a greatly diminished quality of life. Aggressive prostate tumors must be identified, differentiated from indolent tumors, and treated to ensure survival of the patient. Currently, clinicians use a combination of multi-parametric MR including T_2-weighted, diffusion-weighted, and dynamic contrast enhanced imaging to improve PCa detection [2]. While these techniques provide superb resolution, the specificity is often insufficient to identify malignant lesions, particularly in the peripheral zone of the prostate. *In vivo* endogenous sodium imaging of the prostate was first demonstrated by Hausmann *et al.* [2]. Previous studies have shown increased MRI measured tissue sodium concentration (TSC) in brain and breast cancer [3,4]. The overall goal of this study is to determine whether prostate TSC is related to tumor malignancy. The purpose of this report is to demonstrate the feasibility of *in vivo* ^{23}Na MRI in patients with PCa.

METHODS: ***MRI:*** ^{23}Na images were acquired using a custom built endorectal (ER) receive-only RF coil and dedicated asymmetric transmit-only birdcage RF coil, both resonating at the ^{23}Na Larmor frequency on a 3T GE Discovery-MR750 scanner. Three vials (one-milliliter volume) that span the entire length of the receive loop were incorporated into the endorectal coil as reference standards with NaCl concentrations of 30, 90, and 150 mM. All images were acquired using a 3D FGRE sequence; matrix size 32×32, FOV=14, Slice Thickness=6mm, TE/TR=1.7/80ms.

Patients: Four male patients were recruited as part of a multi-modality, image-guided prostate cancer study. Each patient was studied with both ^{23}Na MRI and multi-parametric ^{1}H imaging protocols.

Phantom: *In vivo* images required signal normalization due to the sensitivity profile of the surface ER receive coil. Phantom images were used to normalize for sensitivity using a method developed by Axel *et al.* [1]. Image processing was performed in Matlab (MathWorks, Natick, MA, USA).

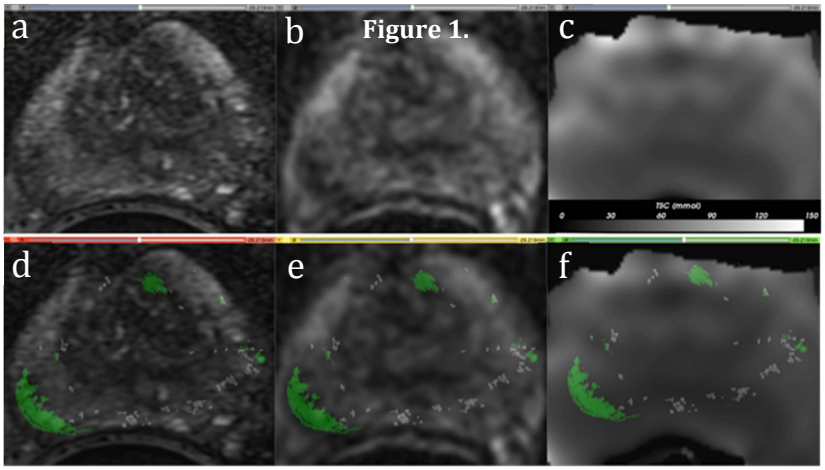

Figure 1.

Registration: The registration pipeline included *in-* and *ex-vivo* volumes, T_2- and T_1-weighted contrasts, and tumor grading from high-resolution histology. Accurate registration of the histopathology slices and the TSC data were made possible through an in-house developed thin plate spline (deformable) extension for 3DSlicer (v4.3.1, www.slicer.org).

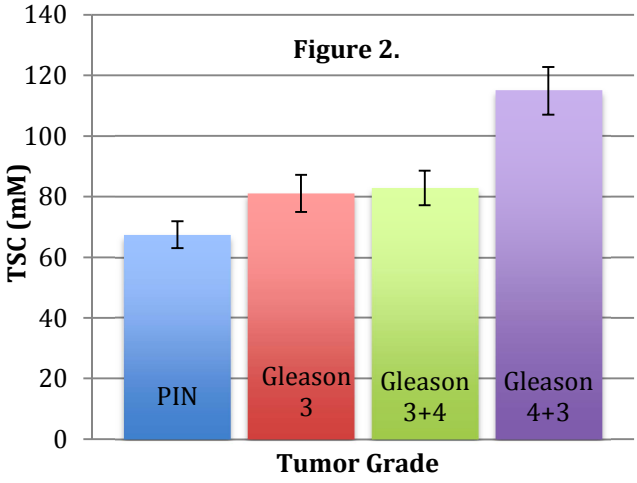

Figure 2.

RESULTS: **Figure 1**, shows a high-resolution T_2-weighted ^{1}H Cube image (a), an axially acquired ^{1}H T_2-weighted image (b), and the distribution of endogenous sodium concentration (c) with corresponding histology contours overlaid (d-f) of an oblique slice through a prostate with biopsy-proven cancer. Green contours represent Gleason 3 and Gleason 3+4 lesions; grey contours represent prostatic intraepithelial neoplasia (PIN, a possible precursor to cancer). **Figure 2**, shows preliminary quantitative analysis of a single patient with biopsy-proven prostate cancer. The observed tissue sodium concentration (TSC) increases as the tumor grade increases.

DISCUSSION: Sodium MRI was successfully used to measure TSC within the prostate including the peripheral and central zones. These preliminary data show a positive correlation between tumor grade and TSC within the prostate, which is consistent with studies in brain and breast cancer [3,4]. Future analysis will determine the relationship between normal prostatic tissue and cancerous lesions.

CONCLUSION: This proposed method produces intensity-normalized ^{23}Na images covering the peripheral and central zones of the *in vivo* human prostate. These preliminary results reinforce the potential use of sodium MR in addition to other multiparametric contrasts as a tool to aid with the diagnosis and staging of prostate cancer.

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