QUANTITATIVE SODIUM MRI OF THE MOUSE PROSTATE

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Introduction:

In healthy tissue, intracellular and extracellular sodium concentrations are actively maintained by an energetic sodium-potassium pump. If normal cellular structure or function is disrupted, this homeostasis can be compromised resulting in a change in the total tissue sodium concentration. Sodium magnetic resonance imaging has been used previously to detect abnormalities in the tissue sodium concentration resulting from various pathological conditions including stroke(1), breast cancer(2) and brain cancer(3). Based on this previous work, it is hypothesized that tissue sodium concentration may also be used to detect sodium changes in the prostate related to the presence of prostate cancer. The purpose of this study is to develop a method for quantitative sodium magnetic resonance imaging of the murine ventral prostate.

Methods:

All experiments were performed on a 31 cm horizontal bore, 9.4T Varian (Palo Alto, CA, USA) small animal imaging system. A loop-gap radiofrequency coil with a length of 18 mm (Figure 1) was constructed on a cylindrical former with a diameter of 35 mm. The coil was dual-tuned to both proton (400.2 MHz) and sodium (105.86 MHz) frequencies by pole insertion(4), and the component values were chosen to favour sensitivity at the sodium frequency. Matching was achieved using a capacitive matching network that could be adjusted for both high and low gamma nuclei, and balancing was achieved at both frequencies using a pair of in-line cable choke baluns. Imaging was performed on a group of five healthy, five month old BALB/c male mice that were anesthetized using isoflourane gas. High-resolution FSE images (sagittal orientation, TR/TE=5000/27ms, echo train length= 8, echo spacing=9ms, effective echo=3, FOV=32x32mm, slice thickness=0.3mm, matrix=256x256, 64 slices, 8 averages) were acquired at the proton frequency to identify the location of the prostate. Sodium images (sagittal orientation, FOV=32x32x16 mm, matrix=32x32x16, 30 averages) were then acquired using a three-dimensional FLASH sequence with short TE (0.6 ms) and long TR (300 ms) to suppress both T1 and T2 signal contrast. A short echo time was achieved using a partial (53%) readout acquisition, combined with a readout bandwidth of 20 kHz. The tissue sodium concentration was estimated by fitting pixel intensities to a linear model based on two sodium vials with concentrations of 100 and 200 mM. From phantom experiments, the B_1 profile of the coil was found to be non-uniform along the axis of the coil, but highly uniform within sagittal slices (orthogonal to the coil axis). Therefore, to avoid B_1 related uncertainties, sodium quantification was performed separately in each sagittal slice using the reference vials at the same slice location. The average sodium concentration in the ventral prostate was determined by defining the prostate boundary in the proton images, and measuring the sodium concentration within that same boundary in the quantitative sodium images. Regions of interest were created using OsiriX (OsiriX Foundation, Geneva, Switzerland).

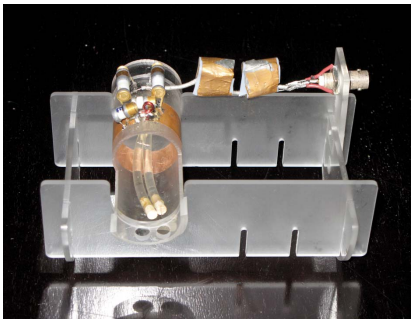

Figure1. Dual-tuned loop gap.

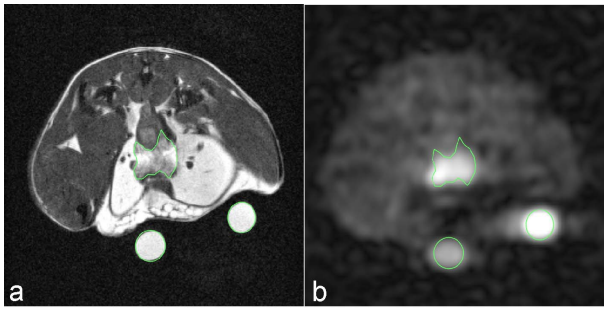

Figure 2. T2 weighted proton image (a), and sodium images (b) taken from the same slice location. Ventral prostate and sodium reference vials are outlined in green.

Table 1.

Mouse	Prostate [Na] (mM)
#1	119
#2	119
#3	144
#4	147
#5	120
Average	**130±14**

Results:

Proton FSE images (Figure 2a) demonstrated clear delineation of the ventral prostate and surrounding anatomy. The ventral prostate was also clearly visible in the sodium images (Figure 2b), as it contained a higher sodium concentration than all surrounding structures with the exception of the bladder. The average sodium concentrations for each of the 5 mice scanned are shown in Table 1, as well as the group average, which was found to be 130 ± 14 mM.

Conclusion:

This study demonstrates the feasibility of quantitative sodium imaging of the mouse prostate. The high natural abundance of sodium in the ventral prostate of the healthy mouse is advantageous for this purpose. In future experiments, quantitative sodium measurements will be performed in a transgenic mouse model of prostate cancer to determine if sodium changes are observed in cancerous prostate tissue.

References:

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