^{23}Na MRI of *In vivo* Rat Kidneys at 3.0 T: Preliminary Experience

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INTRODUCTION Sodium MRI provides a unique ability to directly measure and determine the tissue sodium concentration (TSC) non-invasively [1]. Early studies have shown the ability to detect cortico-medullary sodium gradient in exposed kidneys [2]. Recently it was demonstrated that the same could be performed in intact rat kidneys [3] and showed that *acute* functional changes can be observed during mannitol- and furosemide induced diuresis [4]. These were performed on a 4.7 T small bore scanner using a transmit / receive surface coil. More recently ^{23}Na MRI in human kidneys was reported [5]. We have implemented ^{23}Na MRI in rat kidneys on a whole body 3.0 T scanner. Since sodium excretion by the kidneys is tightly linked to the oxygen consumption in the renal medulla, changes observed on ^{23}Na MRI should be useful in interpreting those observed on renal BOLD MRI [6].

MATERIALS & METHODS

Imaging: Data were acquired on 3.0 T GE Signa short bore twin speed system (GE Healthcare, Waukesha, WI) equipped with a 4 kW multinuclear spectroscopy RF amplifier using a custom transmit / receive ^{23}Na coil placed within a commercial transmit/receive proton extremity coil. A low-pass quadrature birdcage coil was constructed on a 3-inch (7.62 cm) diameter cylindrical polyvinyl chloride (PVC) form. The coil consisted of eight struts and the final dimensions of the coil were 7.62 cm diameter x 8.9 cm length. Quadrature drive was provided by two inductive loops that were positioned 90 electrical degrees apart and approximately 1.2 cm from the coil elements (struts). A quadrature combiner was obtained from a third party vendor (Aeroflex, Whippany, NJ) and a ^{13}C interface box containing the transmit/receive switch and preamplifier (GE Healthcare, Waukesha, WI) was used. Because of the proximity of the Larmor frequencies between ^{13}C and ^{23}Na, it was recently reported that this interface can be used for ^{23}Na MRI [7]. ^{23}Na MR images of rat kidneys were obtained with a spoiled gradient echo sequence using following parameters (TR/TE = 30/2.7 ms; FA = 60^o,16x16x6 cm^3 FOV, 96x96x10 matrix, 18 NEX, BW = 8.1 kHz, acq. Time ~ 8:40 min). Spatial location matched proton images were acquired with a similar sequence using (TR/TE/FA = 6/2 ms/15^o with a FOV of 16x16x4.8 cm^3, matrix size of 256x256x10). **Subjects:** To-date data was acquired in five Sprague-Dawley rats (250 – 300 gm). In two animals, data was acquired pre- and post-furosemide (*iv* 10 mg/kg). **Data analysis:** Standard reconstruction provided on the scanner platform was used. The signal intensity measured on the ^{23} Na MR images was translated to total sodium concentration (TSC). For the preliminary evaluation, we used the T_1 and T_2 values (at 4.7 T) reported for both tissue and solutions and the formulation by Maril *et al* [3]. For better visualization, the kidneys on the ^{23}Na MR images were segmented using masks created from the corresponding proton images, colorized (using Matlab) and then overlaid them on the proton images.

RESULTS

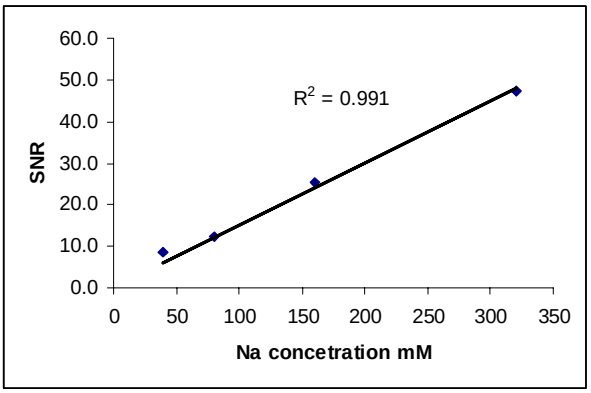

Figure 1: Signal to noise ratio as a function of sodium concentration was measured using phantom solutions of NaCl.

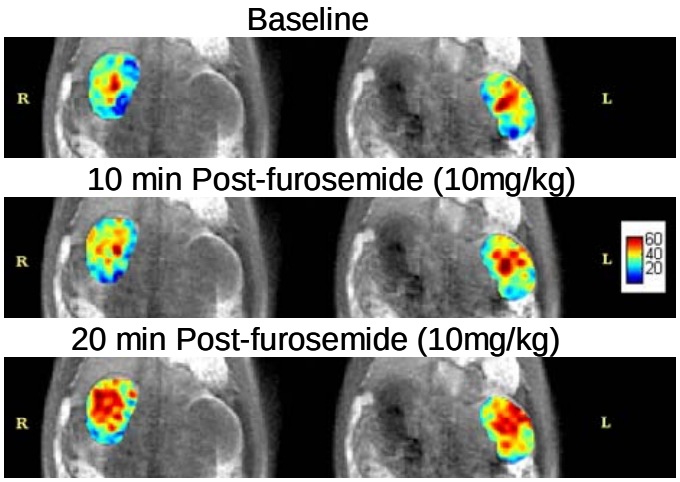

Figure 2: *In vivo* ^{23}Na MR images of rat kidneys obtained before and after *iv* administration of furosemide. Note the clear increase in the signal intensity post-furosemide. This is in agreement with previous reports [4] and is consistent with the increased tubular volume and the Na concentration in the urine (within tubules) and resulting in a diminished cortico-medullary differentiation. A saline bag containing 616 mM of NaCl was placed within the FOV to serve both as a loading phantom and as a reference signal for *in vivo* intensity calibration. We estimated the maximum total sodium concentration (TSC) within the kidney to be about 280 mM using the formulation suggested by Maril *et al* [3]. Post-furosemide, the maximum intensity did not increase but the spatial extent of high TSC increased.

DISCUSSION

Preliminary data presented here support the feasibility of performing ^{23}Na MRI *in vivo* rat kidneys on a whole body 3.0 T scanner equipped with multinuclear capability. In combination with standard proton extremity coils, position matched proton and ^{23}Na MRI can be obtained with relative ease. The distinct separation of Larmor frequencies allows for placement of both coils in the scanner at the same time. The ability to perform ^{23}Na MRI on a whole body scanner may allow for more widespread use of this functional MRI method combined with other proton based techniques [8]. The spatial resolution, 1.6x1.6x6 mm^3 is limited when compared to typical resolution of 0.5x0.5x3 mm^3 used for BOLD MRI. This could explain the absence of clear distinction between cortex, outer and inner medulla. Further improvements in SNR are possible by reducing the echo time (2.0 ms) to include more of the short T_2 component. However this will necessitate use of higher bandwidth (15 kHz) increasing the noise, which can be compensated with more averages.

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