Initial Experience with Sodium MRI of Phantoms and Human Brain at 9.4 Tesla

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INTRODUCTION:

Our initial experience with the 9.4 Tesla scanner for human imaging has focused on sodium MR imaging with twisted projection imaging (TPI) [1]. We have used phantoms to measure signal to noise improvements compared to 3T with resultant improvements in spatial resolution and specific absorption rates (SAR). The first human brain sodium images have been acquired within FDA guidelines for SAR with reduced acquisition times as would be expected compared to 3T.

METHODS:

The 9.4 Tesla magnet and head gradient set (GE Healthcare, UK) were custom built for human imaging (clear magnet bore diameter of 80cm, clear gradient bore access of 36cm with isocenter access at 18cm from patient end of gradient housing) and interfaced to spectrometer electronics (Bruker Biospin, Germany) to provide a full imaging suite for proton and non-proton imaging including capabilities for SAR monitoring, and higher order shimming (14 channels, driven by power supplies from Resonance Research, Inc., MA). A modified birdcage volume RF coil (diameter 26cm) tuned to sodium frequency (105.9MHz) was used for all experiments. The resolution phantom was a sphere filled with 150mM sodium chloride but containing a line of rods of 4 different sizes (25.6, 19.1, 12.7, 6.4mm, respectively). The smallest rods were placed in two pairs separated by their diameter. This phantom was used to establish the experimental spatial resolution of the sodium images. Human imaging was performed on the only individual permitted to enter the magnet to obtain in vivo tissue sodium concentrations (TSC) for comparison to 3T [2]. Calibration phantoms contained 30 and 90mM sodium chloride. Sodium T1 time was measured using a progressive saturation experiment analyzed as a semilogarithmic plot of signal intensity against repetition rate (TR).

Sodium MR imaging was developed using the efficient TPI sequence using parameters that avoided T1 saturation by appropriate choice of TR and minimized T2 signal loss by using the shortest TE (TR = 120ms, TE = 0.41ms, flip angle = 90°, number of averages = 1, maximum gradient strength 4mT/m, resolution = 5x5x5mm^3, number of projections for radial fractions of 0.4 and 1.0 = 2070 and 5100, respectively, giving total acquisition times = 4.14 and 10.2minutes for radial fractions of 0.4 and 1, respectively) [1]. Sodium images were reconstructed and quantified as previously described [1,2,3].

RESULTS:

Figure 1 shows the sodium images of the phantom for radial fractions of 1.0 and 0.4 with corresponding SNR of 20.2 and 18.6 and total acquisition times of 10.2 and 4.1 minutes, respectively. T1 of sodium in free solution was 45ms. Gradation of signal intensity shows the B1 variation across the field of view. Figure 2 shows representative partitions from the human brain sodium images in three planes with a SNR of 25. Quantitative tissue sodium concentrations of brain parenchyma vary between 30 and 36mM, which are similar to, published results from longer acquisitions at 3T [2]. SAR limits set by the FDA guidelines were not closely approached (<25%) during these in vivo acquisitions despite the short TR. Field homogeneity of less than 0.4ppm over the human head was achieved by shimming on the sodium signal.

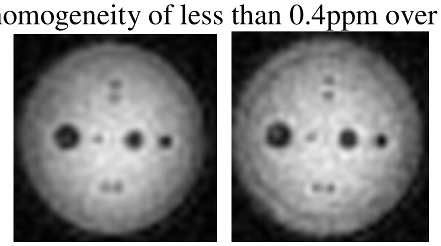

Figure 1. One partition from 3D Na TPI dataset acquired with radial fraction of 1.o (left) and 0.4 (right). The separation of the small rods is evident.

Figure 2. Representative partitions from 3D Na TPI dataset of human brain acquired with radial fraction of 0.4 in 4.1 minutes at SNR = 25 in axial, coronal and sagittal planes.

DISCUSSION:

Sodium imaging has been achieved on this 9.4T scanner designed for human imaging with acceptable spatial resolution for quantification achieved previously at 3T but at shorter acquisition times. Homogeneity and SAR are not limitations.

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2. Thulborn KR, Gindin TS, Davis D, Erb P. Radiology 1999;139:26-34. 3. Jackson JI, Meyer CH, Nishimura DG, Macovski A. IEEE Trans Med Imag 1991;10:473-478. Grant acknowledgement: PO1- NS386760.