Sodium MRI Multi-Echo Sequence for Simultaneous Ultra-Short Echo Imaging and T2L* Mapping at 7T with a 12 Channel Phased-Array Coil

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Introduction

To maximize signal-to-noise ratio (SNR) and minimize relaxation weighting, ultra-short echo (UTE) readouts have been generally been favored for sodium MRI. UTE methods have also been used to measure total sodium concentration (TSC) in tissues [1], although this typically requires accurate mapping of the B_1 field. B_1 measurements are typically noisy and error prone, making good TSC measurements difficult unless the B_1 is highly homogeneous. Furthermore, UTE methods also suffer from off-resonance and T_2^*-associated blurring in the readout direction, making quantitative measurements with these techniques difficult. A more reliable quantitative parameter for sodium MRI is the measurement of the long component of the transverse relaxation time, T_{2L}^*. By collecting several echoes after the short transverse relaxation component has decayed, the resulting decay curve can be accurately fitted to a monoexponential curve.

UTE methods typically use a radial or spiral readout in two or three-dimensions, followed by gridding onto Cartesian k-space before Fourier transforming to image space. We have found that we can obtain very similar results using an acquisition weighted half-echo readout directly on a Cartesian grid. This approach produce echo times just as short as radial readouts, with the benefit of limiting the blurring artifacts to one image axis. We then followed this half-echo readout with five full-echo standard Cartesian readouts. This imaging sequence has the benefit of producing an image with the highest possible SNR and lowest possible relaxation weighting while also providing a robust quantitative parameter.

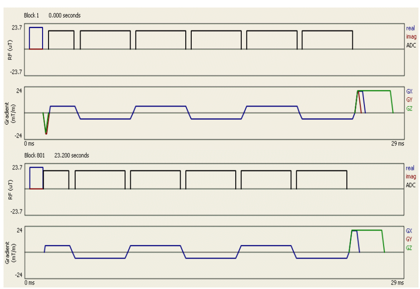

Fig. 1. Half-echo acquisition weighted UTE readout followed by five standard full echo multi-echo readouts. Top image is at the edge of k-space while the bottom image is the center of k-space.

Materials and Methods

A single male subject was imaged under a protocol approved by our Institutional Review Board. Images were acquired on Siemens Magnetom 7T using a vendor-supplied 12-channel transmit/receive single tuned head coil. An RF-spoiled acquisition-weighted gradient half-echo readout with TE: 610μs was followed by five full-echoes with TE: 5.8, 10, 14.8, 18.5, and 22.7; the gradient were rewound in the read and phase direction and a spoiler gradient was applied in the slice direction. The readout polarities were reverse so that both sides of k-space were traversed. The sequence parameters were TR: 30ms, BW=260Hz/px, pulse width: 1ms, 4x4x12mm nomimal resolution, 30 averages, TA: 23.04min. T_{2L}^* was computed by as the inverse of the linear least-squares fit to the negative natural logarithm of signal intensities of the last five echoes. The sequence was written using SequenceTree, a custom-designed pulse-sequence design and editing tool [2]. All image data was processed offline using custom scripts written in MATLAB (Mathwork, Inc.).

Results

Fig.2 shows the magnitude greyscale UTE images (top) and the computed T_{2L}^* values in seconds (bottom).

Discussion

The UTE imaging approach implemented here provides high SNR and minimal blurring artifacts. Significant signal intensity brightening is seen on the periphery in these images (particularly in the occipital region) due the inhomogeneous B_1 field associated with multi-channel phased array coils. This artifactual brightening may be lead to problems in image interpretation in the absence of an B_1 field map to correction image intensities. The T_{2L}^* values computed here are very close to those in the literature. Furthermore, these values do not suffer from B_1 inhomogeneity artifact. Furthermore, since sodium is a 3/2-spin, its linewidth in tissue is dominated by the quadrupolar interaction, limiting the effect of B_0 inhomogeneity and making T_2~T_2^*. In summary, we have implemented a robust sodium MRI technique for simultaneous UTE imaging and T_{2L}^* measurements.

References

[1] Ouwerkerk, et al. *Radiology.* (2003); [2] Magland, et al. *Proc. of the ISMRM* (2006); [3] Fleysher,et al. (2009).

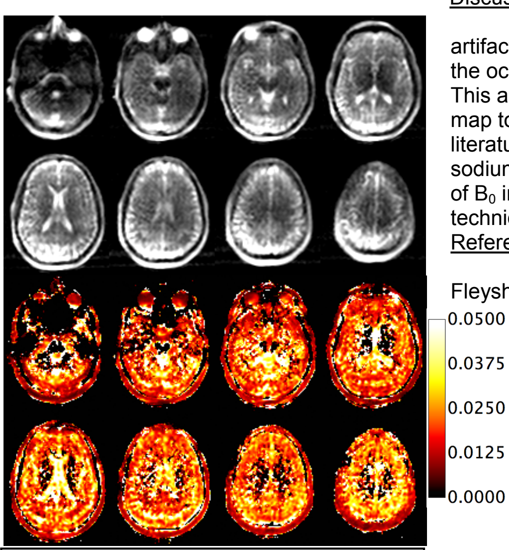

Fig. 2. Magnitude UTE images (top) and T_{2L}^* in seconds (bottom).