Evaluation of B0-Inhomogeneity Correction for Triple-Quantum-Filtered Sodium MRI of the Human Brain at 4.7T

A. Tsang[1], R. Stobbe[1], and C. Beaulieu[1]
[1]Biomedical Engineering, University of Alberta, Edmonton, Alberta, Canada

Background and Purpose**:** In vivo triple-quantum-filtered (TQF) sodium MRI is an attractive technique to probe changes of the intracellular compartment in pathologies such as stroke or tumors. However, static field inhomogeneity (i.e. off resonance) may further degrade the already low signal-to-noise ratio (SNR) due to destructive interference of coherence pathways. Three correction algorithms were proposed with acquisition of TQF images using either 24-step or 12-step phase cycling schemes (1-3). These were successfully demonstrated in agarose gel phantoms but not in humans. The two most recent algorithms using 12-step phase cycling involve a doubling of total scan time (2-3), clearly undesirable for clinical studies. The objective of this abstract is to perform simulations and use one of the correction algorithms (2) to estimate the amount of signal loss on all slices in human brain sodium TQF imaging and thus determine whether the two fold increase in scan time is warranted.

Methods**:** Simulation – Relative transverse magnetization at the beginning of acquisition was computed for off resonance frequencies from -140 to 140 Hz in 1 Hz increments to predict signal loss due to B_0 inhomogeneity using a custom program which implements a set of differential equations describing the dynamics of spin-3/2 nuclei (4,5). Experiment – A Varian Inova 4.7T whole-body MRI scanner with a single-tuned 53 MHz RF head coil was used for all imaging. A three-pulse TQF sodium sequence (6) implementing 3D twisted projection readout acquisition was used to image a healthy volunteer with parameters optimized for the brain at 4.7T under the constraint of specific absorption rate (unpublished) (first/second/third RF excitation flip angles=$65^o/90^o/90^o$, pulse width = 1.25 ms, TE/TR = 6/110 ms, τ_{opt}/δ = 6/0.2 ms, averages = 3) and using FOV = 224 mm, 302 number of projections, and twist p = 0.12 to yield spatial resolution of 8 x 8 x 8 mm^3 in 10 minutes. A first TQF image set was acquired with 6-step phase cycling for the first two RF pulses starting at 30^o and 120^o respectively followed by a second acquisition with starting phase of 120^o for the first two RF pulses (2). The final corrected TQF image was obtained from the square root of the summed squared magnitude of the two TQF image sets. The off resonance parameter ($\Delta\omega$) was computed from two single-quantum (SQ) sodium images acquired in 36 seconds each at different echo times (1) (flip angle = 90^o, pulse width = 0.8 ms, TR = 120 ms, TE = 0.5 and 5.5 ms, averages = 1) using an identical twisted projection readout set as described above. A mask was created from the SQ image acquired with TE = 0.5 ms to exclude voxels outside the brain.

Results and Discussion**:** The relative transverse magnetization computed from simulation of the TQF sequence using brain model taken from previous study (7) with optimized human brain imaging parameters (Figure 1) and also a more 'standard' imaging approach (i.e. 90^o flip angle for all three RF pulses and short pulse width of 0.5 ms) did not demonstrate symmetrical signal loss about the on resonant case as was shown earlier (2). In the TQF images (Figure 2), the correction algorithm appeared to have restored signal only around the nasal sinus and on inferior slices in regions outside the brain. It could also be observed that the correction did not completely restore signal in the anterior portion of the frontal lobe. The majority of brain tissues did not demonstrate improvement on the corrected over the 'raw' TQF images. In fact, the B_0 maps indicated that the off resonance frequencies in brain tissues were mostly between -5 to 5 Hz which translates to about 10% signal loss using Figure 1. The SNR was not expected to be improved using the correction algorithm as the second TQF image set only acquired signals to correct for the off resonance frequencies that correspond to relative transverse magnetization minima. Therefore the doubling of scan time required for the correction does not seem to be warranted. In fact, the increase in scan time would be better used to obtain smaller voxel size or improve SNR.

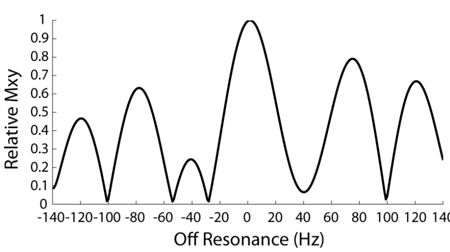

Figure 1 – The predicted loss of transverse magnetization due to the use of long RF pulse widths and smaller first flip angle is not symmetrical about the on resonant case. The minima in the central lobe at -30 and 40 Hz is due to the τ = 6 ms.

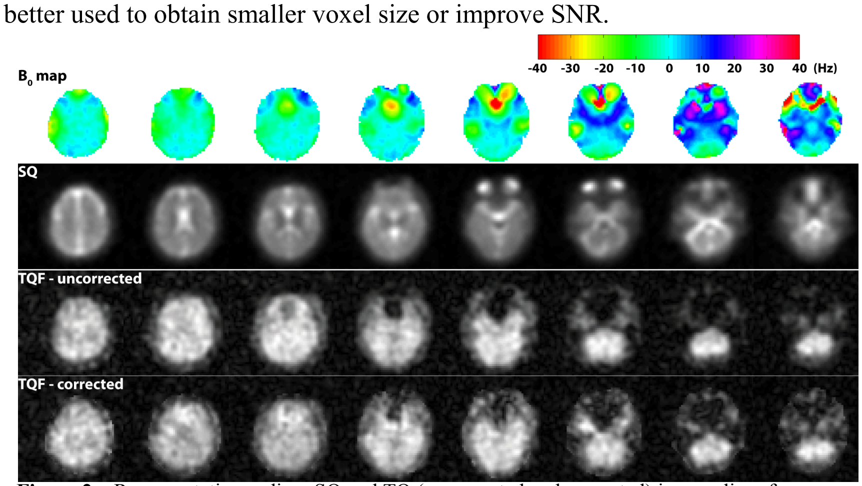

Figure 2 – Representative sodium SQ and TQ (uncorrected and corrected) image slices from a healthy volunteer together with the corresponding B_0 maps indicating that much of the brain has off-resonant frequencies within ± 5 Hz and have little signal loss. There are some small temporal and anterior regions that appear to have signal restored by the correction algorithm.

References**:** (1). Tanase C. J Magn Reson 2005;174:270. (2). Matthies C. J Magn Reson 2010;202:239. (3). Fleysher L. NMR in Biomedicine 2010. (4). Hancu I. J Magn Reson 2000;147:179. (5). Van der Maarel. Concepts Magn Reson Part A 2003;19A:97. (6). Jaccard G. J Chem Phys 1986;85:6282. (7). Stobbe R. Magn Reson Med 2008;59:345.