Feasibility of Intermolecular Zero Quantum MRI at 1.5T

L.-S. Bouchard[1], S. Ahn[2], R. R. Rizi[2], T.-Q. Li[3], D. A. Roberts[2], J. S. Leigh[2], M. D. Schnall[2], W. S. Warren[1]
[1]*Department of Chemistry, and* [3]*Department of Psychology, Princeton University, Princeton, NJ 08544*
[2]*Deparment of Radiology, University of Pennsylvania Medical Center, Philadelphia, PA 19104*

Introduction

In recent years *in vivo* MRI contrast based on intermolecular multiple quantum coherences (iMQC) has been demonstrated in cat brain[1], rat brain[2] and more recently in human brain.[3] It is well known from solution NMR that iMQCs arise from dipolar couplings between spins separated by 100 μm - 1 mm.[4,5] The contrast mechanism *in vivo* is poorly understood and needs further investigation but appears to be fundamentally different from conventional MRI based on relaxation times. Preliminary studies on rat brain have shown that intermolecular zero quantum (iZQ) MRI can distinguish normal form pathogenic tissues.[2,3] ZQ images have lower SNR than conventional gradient echo or spin-echo images but their inherent contrast could potentially be useful clinically. Most *in vivo* studies to date were done at high field strength (4T or higher). The present study demonstrates that ZQ MRI can be performed with sufficient SNR on a clinical 1.5T system.

Methods

MR imaging was done at the University of Pennsylvania Medical Center on a 1.5T GE MR system (GE Medical Systems, Waukesha, WI) equipped with echospeed capabilities and a birdcage head coil. The pulse sequence is a variant of EPI to which several additional pulses were added (Fig. 1), as described elsewhere.[2] The correlation gradient pulse had an amplitude of 2 G/cm and a width of 4 ms, enabling selection of dipolar interactions separated by approximately 930 μm.

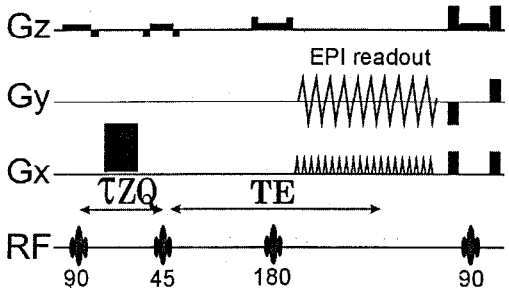

Figure 1. Spin-echo zero quantum pulse sequence with EPI readout. The prototype sequence consists of a 90° pulse followed by a 45° pulse. A correlation gradient pulse (Gx) is applied along the **x**, **y** or **z** directions. A combination of magic angle gradient pulses is played at the end of the sequence to eliminate stimulated echoes between each TR.

Initial control experiments were done to confirm that the ZQ signal is authentic. These involved subtracting two images in which the direction of the correlation gradient pulses was varied from **x** to **y**. This subtraction gives no signal (Fig. 2), as expected.[3] The parameters were: 1-shot EPI, τ_{ZQ}=8 ms, TR/TE=5000/200 ms, matrix=64x64, FOV=24x24 cm, slice thickness=5 mm and 4 NEX. Additional experiments showed that the ZQ signal increases with increasing TE, up to a maximum value, and then decreases due to T_2 decay. Therefore, the signal strength can be optimized by choosing TE close to T_2.

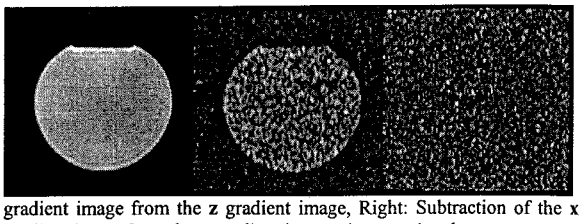

Figure 2. 1.5T images of a spherical silicone oil phantom. Left: conventional spin-echo EPI, Center: ZQ-EPI with subtraction of **x** gradient image from the **z** gradient image, Right: Subtraction of the **x** gradient image from the **y** gradient image gives no signal.

In vivo ZQ images of the human brain were obtained using the same EPI sequence. Other relevant parameters were: τ_{ZQ}=8 ms, TR/TE=5000/(30-100) ms, matrix=64x64, FOV=24x24 cm, slice thickness=10 mm and 16 NEX. The parameters in the ZQ pulse sequence were not optimized. Similar images with a TE of 100 ms may not be obtained at 4T due to the shorter T_2.

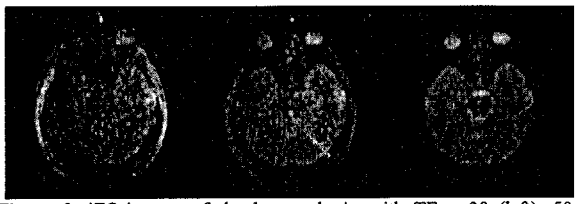

Figure 3. iZQ-images of the human brain with TE = 30 (left), 50 (center) and 100 (right) ms at 1.5 T. The SNR ranges from 4 to 5 in regions near the center of the section.

Discussion

These preliminary results indicate that iZQ MRI is feasible on a 1.5T clinical imager. Unlike conventional MRI sequences, the signal in ZQ images is proportional to the *square* of the propton density. Despite the fact that thermal polarization is lower at low field strength, the shorter T_1 of tissues allows a greater fraction of the total magnetization to recover within a given TR period. This provides enough magnetization to generate the ZQ signal. Furthermore, the ZQ signal increases with TE but is limited by T_2 decay. The longer T_2 of biological tissues at low field strengths allows for longer TEs to be used. At the present time, the ZQ contrast mechanism in tissues is poorly understood and warrants further studies of the effects of various *in vivo* factors (blood flow, paramagnetic molecules, tissue microstructure). Clinical studies at University of Pennsylvania Medical Center are currently underway to investigate the usefulness of iZQ MRI.

References

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