Feasibility of Intermolecular Zero Quantum MRI at 1.5T

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Introduction
In recent years in vivo MRI contrast based on intermolecular multiple quantum coherences (iMQC) has been demonstrated in cat brain1, rat brain2 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.3,5 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.6 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.](image)

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.5 The parameters were: 1-shot EPI, T2,q=8 ms, TR/TE=5000/200 ms, matrix=64x64, FOV=24x24 cm, slice thickness=10 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 T1 decay. Therefore, the signal strength can be optimized by choosing T1 close to T2.

![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 y gradient image, Right: Subtraction of the x gradient image from the y gradient image gives no signal.](image)

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 proton density. Despite the fact that thermal polarization is lower at low field strength, the shorter T1 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 T1 decay. The longer T1 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