A Double Quantum fMRI Study of Motor Activation Using a Single-shot Spiral Data Acquisition at 4T

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Introduction

The purpose of this study was to develop a fMRI technique with contrast dependent on intermolecular double quantum coherence (iDQC). Long-range intermolecular multiple quantum coherence phenomena have been observed for several years in solutions [1-3], but an early attempt to use iDQC contrast *in vivo* gave poor results [4]. A recent study of rat brain demonstrated that zero-quantum coherence produces contrast enhancement between normal and pathogenic tissues [5]. In this study, an improved iDQC imaging sequence based on spiral data acquisition was developed and used for single-shot fMRI study.

Methods

An iDQC pulse sequence was implemented on a GE Signa 4T echo-speed medical scanner. A schematic representation of the sequence is shown in Figure 1. It differs from the sequence in refs [3-4] by addition of an echo time, which is expected to dramatically increase signal as discussed in reference [5]. On-line calculation of the spiral readout waveform [6] was used. The sequence was extensively tested using a spherical mineral oil phantom. In contrast to conventional spin-echo and stimulated echo signals, iDQC images demonstrated signal enhancement with increased TE. Another simple test performed was to vary the orientations of the correlation gradients pulses.

For the dynamic fMRI data acquisitions the following parameters were used: t1=7.6ms, TE/TR=40/5000 ms, matrix size 64x64 over FOV of 220 mm^2, slice thickness = 10 mm and five contiguous slices. The amplitude and duration of the first correlation gradient were 2.2 Gauss/cm and 1.6ms, respectively. Five volunteers (male, aged 21-36) participated in the study. The activation paradigm consisted of 8 blocks of activation epochs interleaved with resting periods. The activation epoch was self-paced 40s finger tapping. A significance criteria of P<0.001 and a minimum cluster size of 3 pixels were used. Both positive and negative responses were evaluated.

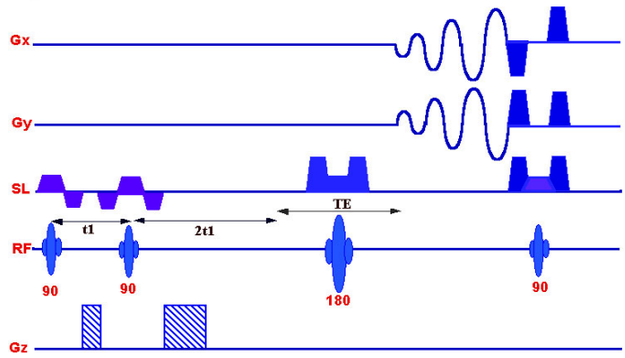
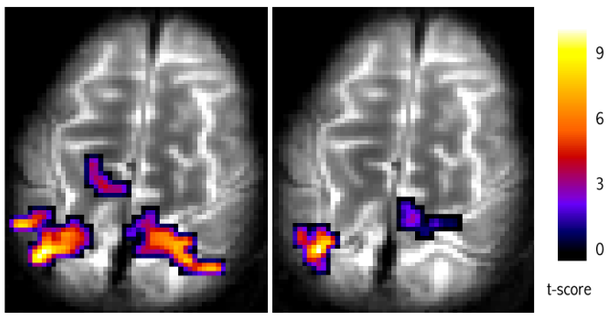


Figure 1. Pulse sequence for acquiring double quantum coherence MRI. The primary sequence consists of two 90^0 pulses combined with a pair of coherence selection gradient pulses (Gz). A single-shot spiral readout was used for data acquisition after the 180^0 refocusing pulse. A complex scheme of spoiler gradient and a 90^0 RF pulses were used after each readout to avoid inter-scan gradient recalled echoes.

Results

A representative iDQC activation map in response to motor activation is shown in Figure 2. Compared with BOLD results, the activation volume detected by iDQC imaging is significantly less and the activation is usually located in peripheral regions of the BOLD activation. The activation induced functional contrast is listed in Table 1 for each subject. For this set of parameters, the DQC functional response was normally negative. The average DQC functional contrast over 5 subjects was about 12%.



(a) BOLD (b) DQC

Figure 2. DQC activation map in comparison with BOLD.

Table 1. Average functional contrast of BOLD and DQC at 4T

Subject	BOLD (TE=30ms)	DQC
1	4.6%	-9.8%
2	5.1%	-10.6%
3	3.2%	-15.2%
4	3.1%	-14.0%
5	4.3%	-12.3%
Average	4.1±0.8%	-12.4±2.3%

Discussion

In this preliminary study, we have demonstrated a totally new MRI contrast that can be used to detect neuronal activation. The functional contrast is improved by a factor of 3. The SNR of an iDQC image is much lower than that for a GRE image, but at the present stage, parameters used for the iDQC fMRI measurements are not optimized for the best SNR and functional contrast. The mechanisms responsible for the negative functional activation in iDQC imaging have not yet been well characterized. It might be due to perturbations in the dipole demagnetization field caused by neuronal activation.

References

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