Functional MRI at 3T using spin echo and gradient echo intermolecular double quantum coherence acquisitions

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Introduction: Inter-molecular double quantum coherence (iDQC) (1) has been implemented in functional MRI (fMRI) studies to achieve activation contrast higher than that of the conventional single quantum coherence (SQC) (2, 3) acquisitions. For a typical iDQC sequence, after the 90 degree slice selective RF pulse, a β pulse with a flip angle of 60° (or 120°) is applied at a time interval of τ. Spin echo (SE) iDQC sequences, where a refocusing 180° pulse is applied between the β pulse and the data acquisition, are less sensitive to the large scale susceptibility changes than the gradient echo (GE) iDQC sequences. The iDQC signal and contrast depend on: τ, TE, TR as well as $T_2(T_2^*)$ and T_1. In a recent study (3), using the parameters suggested in reference (4), high functional contrast was detected using the GE iDQC sequence, but almost no activation was detected using the SE iDQC method. In our study, activation was detected using both GE and SE iDQC sequences in visual stimulation studies with optimized τ and TE.

Materials and Methods: SE and GE iDQC sequences with EPI readout were applied on a Siemens 3T scanner scanning six volunteers, along with the conventional GE-SQC fMRI sequence. Numerical analyses were applied first to find the right choices of the scan parameters to reach the optimized functional contrast. For GE iDQC sequences, τ of 5 ms and 20 ms were studied and labeled as GE-iDQC5 and GE-iDQC20 respectively. For SE iDQC, τ was 20 ms. Due to the scan time limit, the three iDQC sequences were applied alternately on different volunteers (Table 1). The left and right visual cortices were alternately activated, 30 seconds in each period, with a flickering checker-board stimulation pattern. GE-SQC scan was first applied within 4 minutes with TR/TE of 3s/300ms. 24 slices (FOV:22 cm, slice thickness: 5mm) were acquired. For iDQC sequences, a single slice of 10 mm (FOV 30 cm) covering the primary visual cortex was acquired in 12 minutes (TR 5s) for each scan with TE = 80ms ≈ T_2.

Results: As shown in Table 1, although there is a large variation among subjects, the percentage signal changes of the iDQC sequences are about twice as high as that acquired using the SQC fMRI sequence. The sample activation maps a) for conventional GE-SQC, and b) for SE-iDQC of one subject at the same location are shown in Figure 1, along with the mean time course in c) (red line for GE-SQC, blue line for SE-iDQC). It can be observed that activation generated using SE-iDQC is more localized and higher than that generated using GE-SQC.

Discussion and Conclusion: Based on phantom studies, we found minimum SQC signal contamination in single scan iDQC sequences without 4-step phase cycling. Therefore, to reduce the total scan time in human studies, no phase cycling was used. A long TR of 5s could efficiently eliminate the stimulated echo contamination as previously noted (3). With optimized scan parameters TE ~ T_2 and long τ ~ 20 ms, both the GE and SE iDQC sequences could be used to achieve high brain function activation contrast. The observation that SE-iDQC can detect functional activation may be important for studies at high fields because large-scale susceptibility effects do not mask the SE-iDQC activation signal, while they do on GE-based acquisitions.

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Reference: **1**. Warren WS et al, Science 1993; 262:2005-2009. **2**. Zhong J, et al, MRM 2001; 45:356-364. **3**. Schafer A et al, MRM 2005 ; 53 :1402-1408, **4**. Marques JP & Bowtell R, MRM 2004 ; 51 :148-157

Table 1. Percentage signal changes for left/right side stimulations in individual subjects

Subject	1	2	3	4	5	6	Mean
GE-SQC	3.0/ 2.8	2.2/ 3.9	1.8/ 1.9	2.5/ 2.6	3.2/ 5.0	2.0/ 2.7	2.5/ 3.2
GE-iDQC5				3.8/ 3.7	10.2 /8.2		7.0/ 6.0
GE-iDQC20		4.5/ 7.7	3.3/ 3.4	4.5/ 5.7		4.6/ 9.9	4.2/ 6.7
SE-iDQC	7.9/ 10.1		4.0/ 3.1		3.1/ 4.4	4.6/ 2.6	4.9/ 5.1

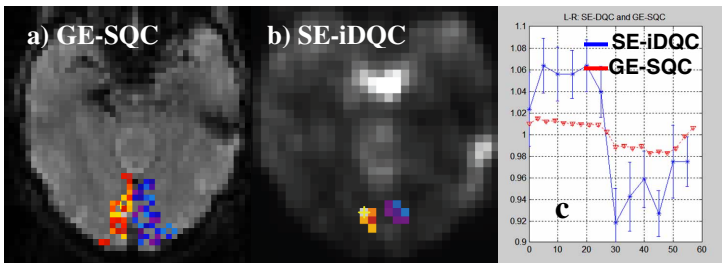

Figure 1. Activation maps of one volunteer: a) is acquired using SQC, b) using SE-iDQC and c) is the mean percentage signal change time course: blue line for SE-iDQC and red line for SQC.