Experimental Phantom Verification of Intermolecular Double Quantum Coherences (iDQC) with Turbo Spin Echo (TSE) Technique: potential benefits for fMRI

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Purpose

Brain fMRI suffers from low signal levels inherent to the blood oxygenation level dependent (BOLD) contrast mechanism. The commonly used echo planar imaging (EPI) sequences also suffer from susceptibility. Turbo spin echo (TSE) sequences have been proposed for fMRI experiments to address some of these issues (1-2). A further enhancement, called intermolecular double quantum coherence (iDQC) increases the BOLD contrast compared to single quantum coherence (SQC) methods (3). Zhong et al. have shown up to 10% signal enhancement in auditory activation iDQC-SE images, compared to 2% changes for SQC-GRE measurements at 1.5 T (4). In this report, the first phantom iDQC images obtained with the TSE technique are compared to iDQC images obtained with EPI.

Methods

A TSE sequence with an echo train length (ETL) of 64 and a single shot SE-EPI sequence (Fig.1-2) were modified on a Philips 1.5 T Eclipse MRI scanner (Philips Medical Systems, Highland Heights, OH) to detect the iDQC signal from the ACR MRI accreditation test phantom. For the iDQC TSE sequence, inter-echo spacing (IES) was 11.8 ms and evolution time (τ) was 8.5 ms. For the iDQC EPI sequence, evolution time (τ) was set to 11.5 ms. The correlation distance (d) of 250 μm was computed from the area of the first iDQC-encoding gradient as represented with diagonal lines in the Figures (amplitude=23 mT/m, rise time=0.433 ms, duration=1.6 ms).

The iDQC signal was validated by successively applying the iDQC-encoding gradients along the x, y, z and magic angle directions. As predicted by theory, the iDQC signal vanished when the magnetic field gradients were applied along the magic angle and the signal level dropped approximately 50% of its maximum value (obtained when the gradients were aligned along the z-direction) when the gradients were applied along x or y directions.

The square grid pattern section of the ACR phantom was imaged using the following sequences; SQC TSE sequence (64 ETL) with matrix=256x256 and NSA=1, iDQC TSE sequence (64 ETL) with matrix=256x256 and NSA=2, iDQC EPI sequence with matrix=80x80 and NSA=2. The common imaging parameters were TR=5 s, TE=29 ms, FOV=30 cm and thickness=10 mm. For SQC TSE sequence, TE was set to 31.5 ms. For signal to noise ratio (SNR) measurements, a uniform section of the ACR phantom was imaged using the same three pulse sequences. The common imaging parameters were TR=5 s, TE=29 ms, FOV=30cm, matrix=64x64, thickness=10 mm and NSA=1. For SQC TSE sequence, TE was set to 31.5 ms. SNR was determined by the standard single image ACR method (mean signal of round ROI divided by standard deviation of background noise signal).

Results

The images obtained using the SQC TSE (64 ETL) sequence, the iDQC TSE (64 ETL) sequence, and the iDQC EPI sequence are presented in Figure 3. The iDQC TSE image has ghosting artifacts along the phase direction because the iDQC-encoding gradients have unbalanced the TSE inter-echo spacing requirement. The phantom image obtained with the iDQC-EPI pulse sequence had significant geometric distortion along the phase-encoding direction due to susceptibility differences and magnetic field inhomogeneities.

The SNR values for the images of the uniform section of the ACR MRI accreditation test phantom, obtained by the SQC TSE sequence (64 ETL), the iDQC TSE sequence (64 ETL), and the iDQC EPI sequence, are as follows; 333.3, 33.6, and 4.0, respectively. iDQC signal was 1% of SQC signal. iDQC TSE (64 ETL) sequence gave a higher SNR than iDQC EPI sequence.

Conclusions

Phantom iDQC images using Turbo Spin Echo technique were obtained for the first time. iDQC TSE is a viable technique for producing fMRI images more quickly than spin echo and with higher SNR and lower susceptibility artifacts than iDQC EPI.

References

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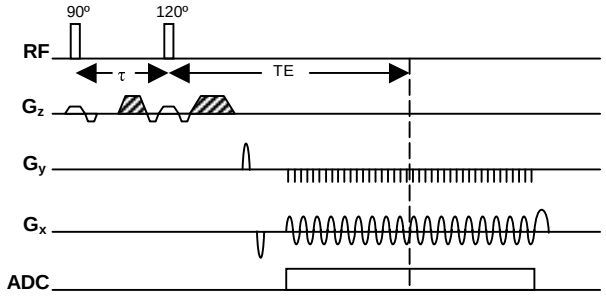

Figure 2. iDQC EPI sequence diagram.

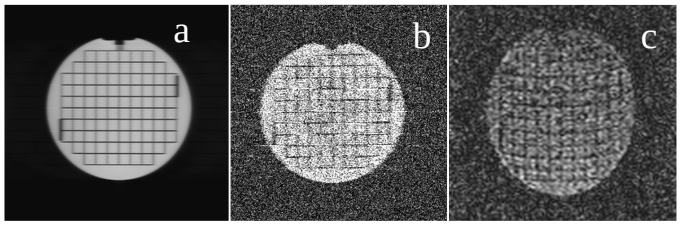

Figure 3. a) SQC TSE image, b) iDQC TSE image, c) iDQC EPI image

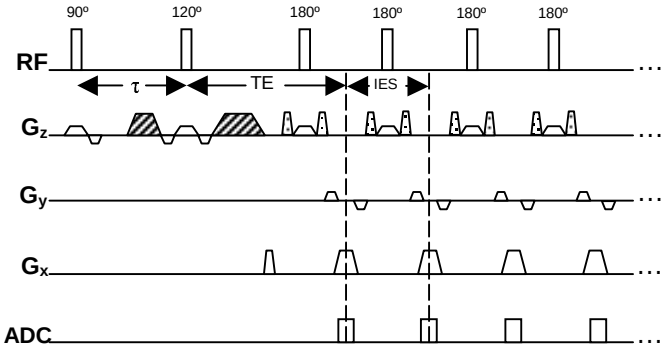

Figure 1. iDQC TSE sequence diagram.