Intermolecular double-quantum coherence imaging without coherence selection gradients

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Introduction

Intermolecular double-quantum coherences (iDQCs) originate from long-range dipole-dipole interactions between spins of different molecules. They have some unique properties different from conventional single-quantum coherence and have been applied for high-resolution MRS under inhomogeneous magnetic fields, novel contrast of MRI, and functional MRI [1-4]. However, low sensitivity of iDQC signal limits their practical applications. In the conventional iDQC imaging experiments, the distant dipolar field (DDF) is generated by coherence selection gradients (CSGs). It was shown that DDF can arise from certain sample geometry in the absence of CSGs [5]. Here, we demonstrate that sample geometry plays an important role in generating DDF in the absence of CSGs, and this DDF can yield stronger iDQC signal than that from the CSGs if an appropriate phase cycling scheme is adopted.

Methods

The pulse sequence is shown in Fig. 1. The CSGs were turned on for the experiments with DDF produced by CSGs (DDF-CSGs), and turned off with DDF produced by sample geometry (DDF-SG). The π pulses in the middle of evolution period (τ) and TE can largely eliminate the effect of macroscopic inhomogeneous field. For the DDF-CSGs, a four-step phase cycling scheme of α (0°, 90°, 180°, 270°) and the receiver (0°, 180°) and the optimal pulse flip angles of α = π/2 and β = 2π/3 were applied [6]. The CSGs were applied along the z direction, with duration δ of 1 ms and strength G of 0.1 T/m. For the DDF-SG, a four-step phase cycling scheme of α (45°, 135°, 225°, 315°) and the receiver (90°, 270°) was employed. The signal intensity is proportional to $\sin^2\alpha\sin\beta$, thus the optimal pulse flip angles are α = π/2 and β = π/2. The experiments were performed on a Varian 7.0T/160 mm research MRI system with a 63/95 mm quadrature birdcage coil. Some main experimental parameters were as follows: TR = 6 s, slice thickness = 2 mm, field of view (FOV) = 40 mm × 40 mm, and matrix size = 128 × 128.

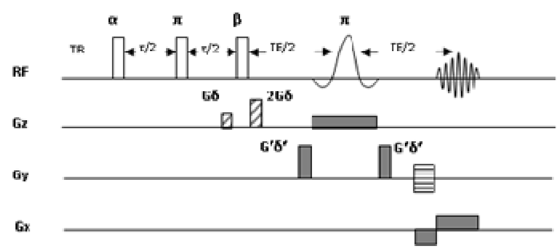

Fig. 1 Pulse sequence used for iDQC MRI. Dashed rectangles are CSGs for iDQCs.

Results and Discussion

Fig. 2 shows the iDQC MR images of a mouse brain. It can be seen that the image acquired by DDF-SG (Fig. 1b) has much higher signal-to-noise ratio (SNR) than that acquired by DDF-CSGs. This shows the possibility of enhancing iDQC MRI signal through using DDF produced by sample geometry. It is noted that, if the magnetization of the sample is isotropy, such as the water phantom with spherical shape, the dipolar interactions are geometrically averaged to zero and thus no net DDF is created by sample geometry. Fig. 3 shows the iDQC images using spherical water phantom with a diameter of 30 mm. The signal intensity almost reduces to zero when using DDF-SG to obtain iDQC signal. However, practical biological samples, such as mouse brain, are always anisotropy and thus DDF produced by sample geometry exits. In the iDQC method with CSGs, diffusion due to the CSGs may cause additional signal attenuation. Note that although diffusion may cause additional signal attenuation in the iDQC method with CSGs, this effect is small [2]. Therefore the exclusion or inclusion of CSGs is not the main reason for the difference in SNR in Fig. 2. The iDQC signal enhancement brought by the DDF created by sample geometry can facilitate iDQC practical applications, such as providing novel MRI contrast.

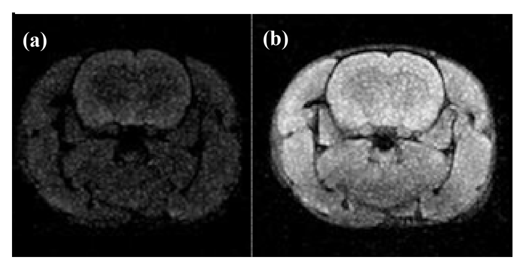

Fig. 2 Mouse brain images using DDF-CSGs (a) and DDF-SG (b). The gray scales are same.

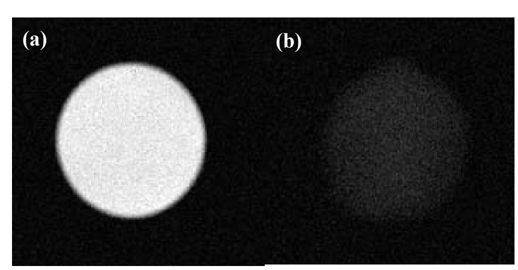

Fig. 3 Images of water phantom with spherical shape using DDF-CSGs (a) and DDF-SG (b). The gray scales are same.

Acknowledgments

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