Fast relaxation induced by SPIO compromises contrast from intermolecular double–quantum coherence in CRAZED–MRI

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Introduction

The CRAZED sequence permits detection of signal generated by intermolecular double–quantum coherence (iDQC). When applied to ^{1}H MRI, a novel type of contrast is obtained [1], in particular, a positive contrast when superparamagnetic iron oxide particles (SPIOs) are present [2, 3]. We demonstrate that the high T_1–relaxivity of SPIOs can cause spurious signal in CRAZED MRI which cannot be attributed to iDQC.

Theory

The signal intensity *S* observed in an iDQC CRAZED experiment depends on the angle Θ between the coherence selection gradient $\vec{G}$ and the static magnetic field $\vec{B}_0$ according to $S \sim |3\cos^2\Theta - 1|$. Hence, for the "magic angle" $\Theta = 54.7°$ no signal is expected ($S = 0$). However, the microscopic magnetic fields generated by SPIOs superimpose with the applied field gradient $\vec{G}$ with the consequence that the direction of resulting gradients varies locally violating the condition $|3\cos^2\Theta - 1| = 0$. Imaging shows bright residual signal in the vicinity of the SPIOs [2].

Methods

Experiments were performed on a 3–T whole–body tomograph (Magnetom Trio; Siemens Medical Solution, Erlangen. Germany). We employed the CRAZED–type pulse sequence in Fig. 1 which consists of three nonselective BIR–4–pulses and one slice–selective 180° pulse (flanked by spoiler gradients), a DQC–gradient filter (with variable spatial direction and duration $\tau = 4$ ms) and a spinecho readout using a slice-selective 180° pulse (TE = 11 ms, TR = 5 s, TA = 5.25 min, nex = 1, matrix = 64×64, FOV = 120 mm, slice = 10 mm, BW = 130 Hz). A container filled with 1% agarose gel was prepared. In a small volume within the container agarose gel loaded with SPIOs (ratio: 1/500, Supravist; Schering AG, Berlin) was deposited prior to complete cooling of the sample.

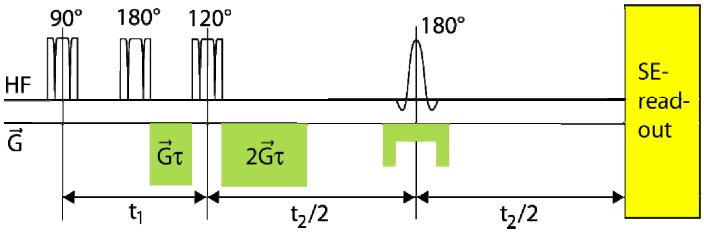


Fig.1. CRAZED–type pulse sequence.

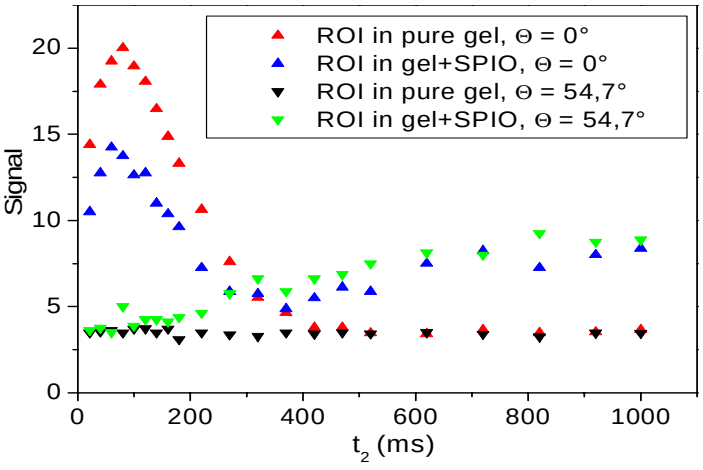
Results and Discussion

iDQC MRI with $\Theta = 54.7°$ showed residual signal in regions where SPIOs were deposited. When the evolution time t_2 was increased (up to 1 s), the residual signal became stronger (Fig. 2) and was independent of the direction of the applied gradient (Fig. 3c, d). Detailed studies of the signal in the vicinity of SPIOs as a function of t_2 showed changes similar to T1 relaxation when t_2 was increased. The expected non–exponential signal–time course (corresponding to non–Lorentzian lineshape of iDQC signal in the frequency domain) could be observed only for $\Theta = 0°$ and short t_2 (Fig. 2). These findings are explained by short relaxation times of water protons around the SPIOs. During the preparation period, the magnetization in these regions relaxes rapidly back to equilibrium. Small imperfections of the 180° refocusing pulses can generate significant amounts of transversal magnetization which is not related to iDQC. The spurious signal can be reduced by minimizing the time intervals t_1 and t_2 and appropriate phase-cycling. In CRAZED MRI experiments with samples that contain SPIOs, the short relaxation times of water protons close to SPIOs must be taken into account when image contrast is analyzed.

References

[1] Warren WS *et al.*, Science 262 (1993) 2005–2009. [2] Faber C *et al.*, J Magn Reson 182 (2006) 315–324. [3] Branca RT *et al.*, Proc Intl Soc Mag Reson Med 15 (2007)

Fig.2 Signal intensity in the CRAZED experiment of Fig. 1 at angles $\Theta = 0°$ and 54,7° as a function of t_2 for ROIs with and without SPIOs.



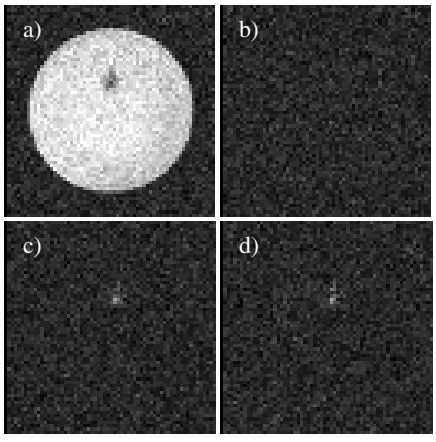


Fig.3 MR images obtained from the gel phantom with the CRAZED technique (Fig. 1), grayscales adjusted in the same manner.

a) $t_2 = 80$ms, $\Theta = 0°$
b) $t_2 = 80$ms, $\Theta = 54{,}7°$
c) $t_2 = 1$s, $\Theta = 0°$
d) $t_2 = 1$s, $\Theta = 54{,}7°$