B1 insensitive MLEV-4 pulse sequence for T2-prep

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Introduction

T2-prep is important for cardiovascular applications. Flow saturation is also important for myocardial or vessel wall imaging. T2-prep often uses CPMG or MLEV-4 type sequence. However, because of B1 inhomogeneity on 3T, inhomogeneous signal loss occurs. Although adiabatic BIR-4 type sequence is robust to B1, it requires large flip angle and high SAR. In this study, B1 insensitive MLEV-4 type preparation pulse was designed and B1 and flow sensitivity were measured.

Principle

Signal intensity of T2-prep reduces in B1 inhomogeneous region in 3T because refocus pulses does not become 180 degree. Flip angle of the refocus pulses was optimized in this study. MLEV-4 type flip angle (90x, αy, βy, -αy, -βy, -90x: Fig. 1) is described like (α,β) in this paper. The absolute value of α and β must be less and more than 180, respectively. In the case with positive ΔB1, α becomes near to 180 and magnetization is refocused correctly. In the case with negative ΔB1, β becomes near to 180 and vise versa. As a result, T2-prep becomes less sensitive to B1.

The crusher gradient is required to cancel the phase error cause by B0 inhomogeneity. The crusher gradient area should be large enough to rotate transverse magnetization for 2π in 1 pixel. The crusher gradient area between refocus pulses is twice of that between 90x and 1st refocus pulse. The flow magnetization is saturated because of the velocity dependent phase error produced by crusher gradient. This is so called flow void.

Materials and Methods

ΔB1 and signal intensity with different (α,β) were simulated with MATLAB. T1 and T2 relaxation were neglected in the simulation.

The signal intensity in inhomogeneous B1 was measured with the water static phantom. T1 and T2 were long enough. 3T scanner without elliptical drive (HDx, GE Healthcare) was used. 3D FSE with 180 degree refocus pulses was used for data acquisition. These were to emphasize ΔB1 and signal intensity might have local maximum at ΔB1=0. Signal intensities were compared between different types of T2-prep.

The water flow phantom was used to measure flow velocity dependent signal intensity with T2-prep. Data acquisition sequence was 3D balance SSFP (FIESTA) that is robust to flow. The flow velocity was measured with 2D Phase Contrast.

The area of crusher gradient (blue in Fig. 1) was 18.37 (μs T/m). T2-prep total time was 23 ms.

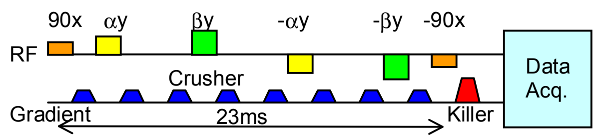

Fig.1: Pulse sequence chart of T2-prep and Data acquisition

Results

The result of simulation was in Fig. 2. X-axis was ΔB1 (%). Y-axis was signal intensity (% to M0). In (α,β)=(180,180) case (red line), signal intensity reduced more than 10% at ΔB1=+/-30%. On the other hand, in (α,β)=(120,180) case (green line), signal intensity at ΔB1=+50% was almost 100%. This was because α*1.5=180 and +/-αy pulses refocused the magnetization correctly. However, if ΔB1 was less than 0%, signal intensity was very sensitive to B1. In (α,β)=(140,-200) case (blue line), signal intensity was more than 95% between ΔB1=-20% and +40%.

Fig.3 was the water static phantom image without T2-prep and ROI position. Signal intensity table with several types of T2-prep was in Fig.4. ΔB1 was almost 0% at ROI2 because signal intensity had local maximum and was almost the same between different types of T2-prep. ROI1 had positive ΔB1 and signal intensity with (α,β)=(180,180) was lower than others. ROI3 and ROI4 had negative ΔB1 and signal intensity with (α,β)=(120,180) was lower. All ROI with (α,β)=(140,-200) was within +/- 10% of T2-prep off case. These trends correspond to the simulation and (α,β)=(140,-200) was the least sensitive to ΔB1.

Fig.5 was the result of water flow phantom measurement. (α,β) was (140,-200). X-axis was velocity. Because signal intensity of 3D fiesta depends a little on flow velocity (green line), the signal intensity % ratio of T2-prep on/off (red line) was also shown. The threshold velocity of the flow void was around 300 mm/s.

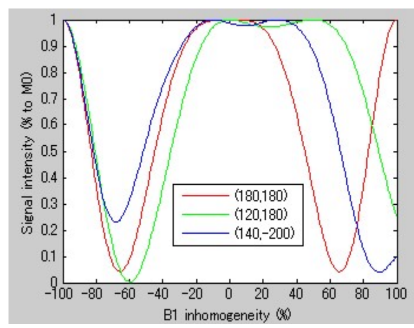

Fig. 2: Simulation result

Fig. 3: Phantom & ROI position

Fig. 4: Table of ROI signal and T2-prep types (Light blue: within +/- 10% of T2-prep off case)

(α,β)	T2-prep off	(180,180)	(120,180)	(140,-200)
ROI1	1873	1353	2102	1894
ROI2	3809	3900	4104	3847
ROI3	1454	1421	1292	1432
ROI4	2516	2211	1765	2319

Discussion and Conclusion

The (α,β)=(140,-200) case was robust to ΔB1 in both simulation and water static phantom. However, by making α less than 140 or β less than –200 in the simulation, signal intensity at ΔB1=0 are suppressed and this was not suitable for homogeneous T2-prep.

Larger crusher gradient area or longer T2-prep total time would realize slower threshold velocity. In this study, T2-prep total time was only 23ms and longer one (i.e. 48ms) was often used.

As a result, T2-prep with (90x,140y,-200y,-140y,200y,-90x) is robust to ΔB1 and can also be used for flow saturation preparation pulse.

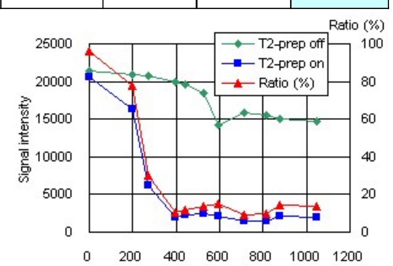

Fig. 5: Flow velocity and signal intensity