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WORKSHOP PRESENTATION Open Access

Optimized saturation pulse rrains for SASHA T_1 mapping at 3T

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Background

SASHA and MOLLI T_1 mapping sequences can have errors in calculated T_1 values when their magnetization preparation pulses do not fully saturate/invert magnetization [1,2]. The commonly used 90°-90°-90° saturation pulse train [3] has poor performance at 3T due to large B_1 field inhomogeneities. We propose that a new hard RF pulse train with numerically optimized flip angles [4] will offer superior performance and reduce errors in SASHA T_1 values due to incomplete saturation.

Methods

Flip angles for a 6-pulse train were optimized by minimizing the maximum residual longitudinal magnetization in Bloch equation simulations performed over ranges of values expected at 3T: 40-120% B_1 scaling, -240-240 Hz off-resonance, 200-2000 ms T_1, and 14 μT B_1 strength. Complete spoiling of transverse magnetization was assumed during spoilers. Optimization code is available at https://bitbucket.org/kelvinc/pulsetrainopt.

Saturation performance for the 90°-90°-90° and the 6-pulse train was measured in a phantom with saturation recovery GRE. B_0 and B_1 maps were calculated using multi-TE and multiple flip angle GRE respectively. A magnetic field gradient was used to produce a range of off-resonance and experiments were repeated with the prescribed pulse train flip angles scaled by 40-120% to emulate B_1 inhomogeneity.

SASHA and MOLLI T_1 mapping were performed using investigational prototype sequences on a 66 kg swine in a 3T system (MAGNETOM Skyra, Siemens AG, Germany). SASHA was acquired using both the 90°-90°-90° and proposed pulse train with a 45° imaging flip angle. MOLLI used an optimized inversion pulse (2) with a 20° flip angle. A B_1 map was acquired using a saturated double angle method with single-shot EPI readouts.

Results

The optimized 6-pulse train flip angles were 115-90-125-85-176-223° with a 33 ms duration. The 6-pulse train had excellent performance (Fig. 1), with an average and maximum absolute residual longitudinal magnetization over the optimization range of 0.27% and 0.87% respectively. Experimental data had excellent agreement with simulations.

In the swine study, the B_1 varied from 30-95% across the left ventricle (LV) profile (Fig. 2). MOLLI and 90°-90°-90° SASHA T_1 maps show a >50% artifactual decrease in T_1 values with reduced B_1 values in the lateral wall. SASHA T_1 values using the 6-pulse train are more spatially homogeneous (1386±70 ms across the entire LV profile).

Conclusions

A saturation pulse train optimized for B_0, B_1, and T_1 ranges expected at 3T was shown to have residual longitudinal magnetization of <1%. In-vivo swine MOLLI and SASHA data with the commonly used 90°-90°-90° pulses had >50% T_1 variation due to B_1 inhomogeneity while 6-pulse train SASHA had a 5% coefficient of variation.

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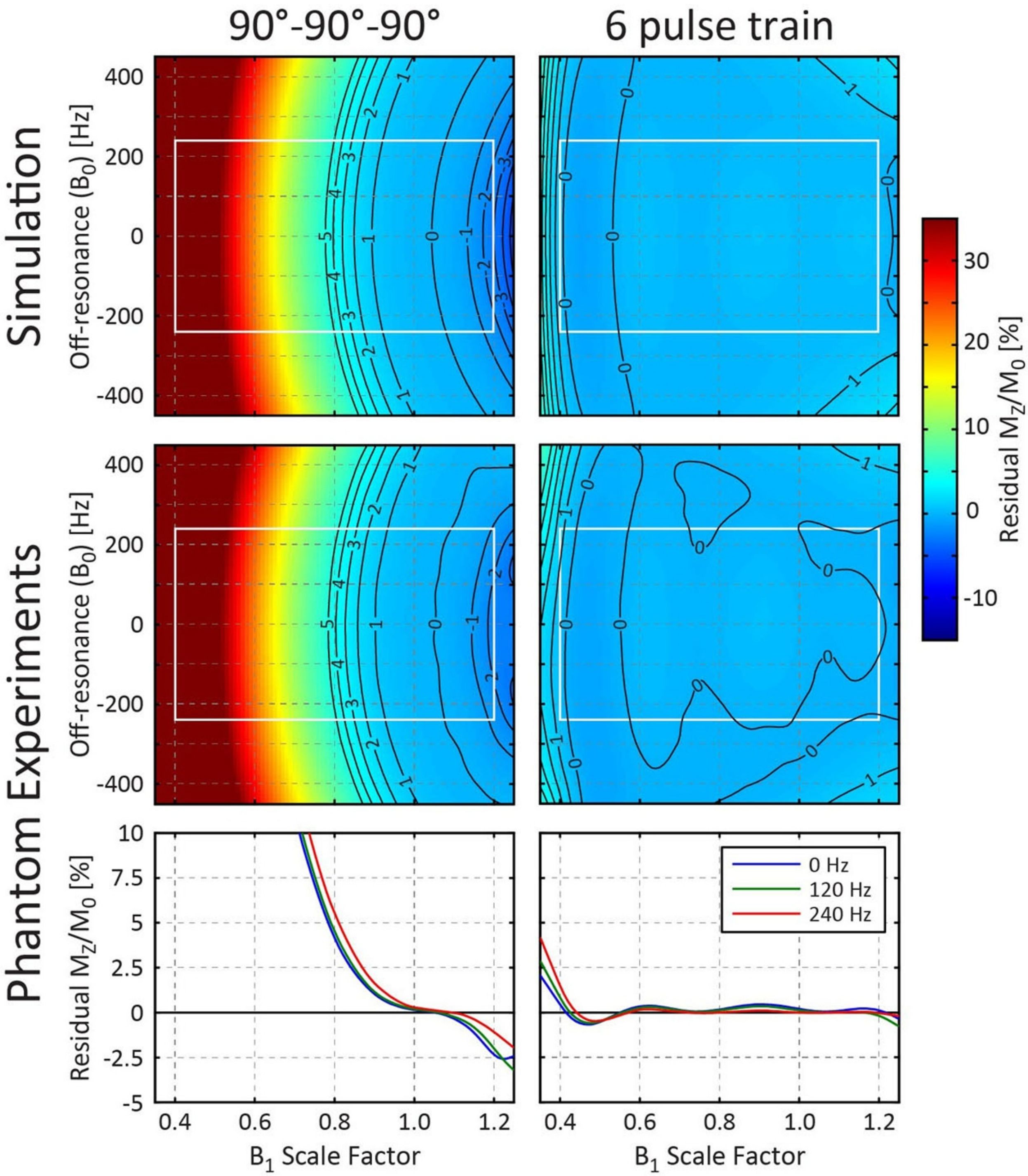

Figure 1 Simulated and experimentally measured residual longitudinal magnetization for a commonly used 90°-90°-90° saturation pulse train and a proposed 6 pulse train. White boxes denote the 3T optimization range.

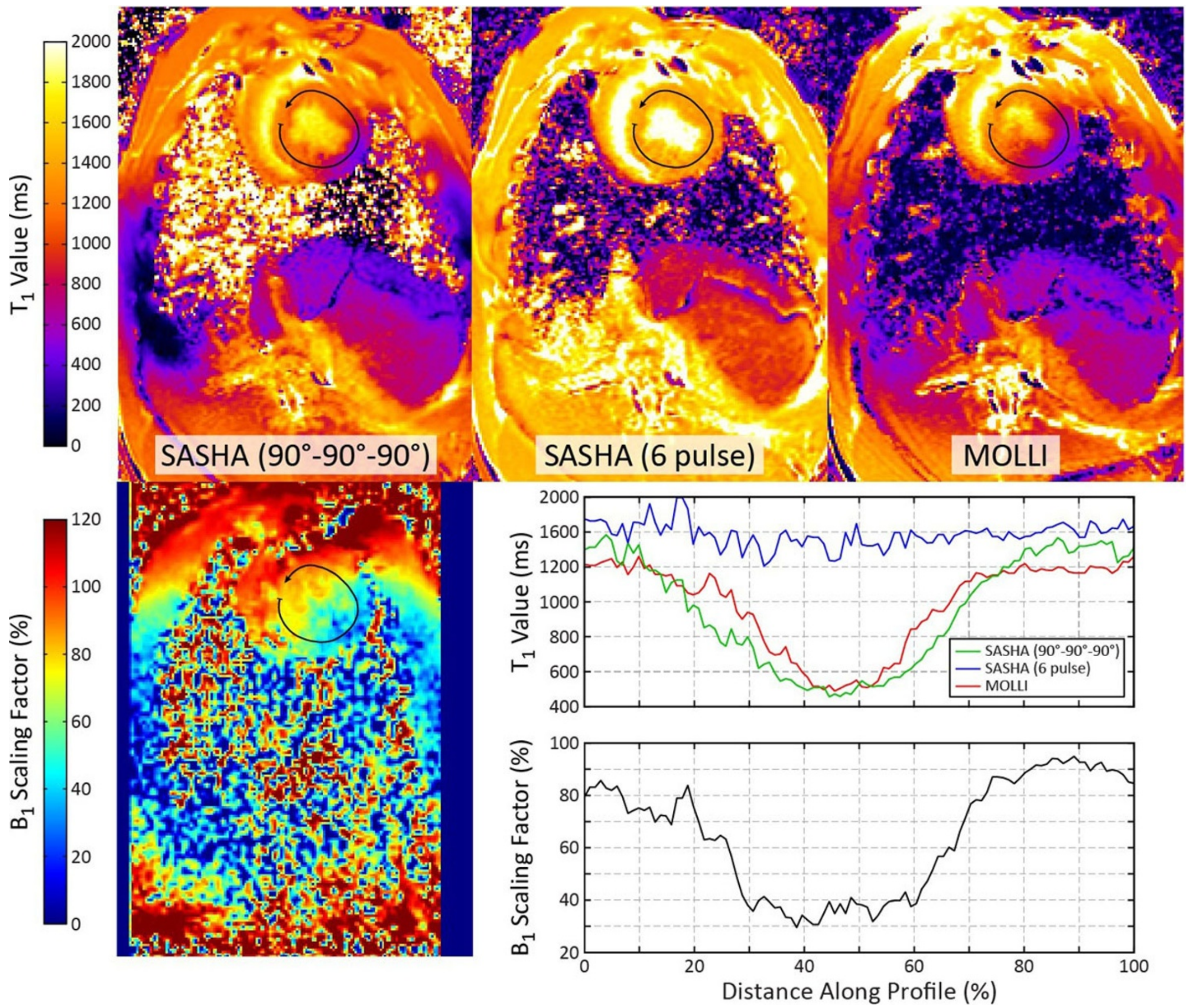

Figure 2 A B_1 map (bottom left) and T_1 maps (top row) using SASHA with a reference 90°-90°-90° saturation pulse, SASHA with a proposed 6 pulse train, and MOLLI in a swine. A profile of T_1 values along the left ventricular wall shows decreased T_1 values in the lateral wall coinciding with reduced B_1 values.

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