

POSTER PRESENTATION

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Numerically optimized radiofrequency pulses for robust and low-power cardiovascular T_2 preparation at 3T

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Background

Cardiac magnetic resonance imaging (CMR) has been shown to benefit from the higher signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) available at

higher magnetic field strengths; however, in practice, CMR remains limited by the need for higher radiofrequency (RF) pulse power, which is in turn limited by the maximum specific absorption rate (SAR). For example at

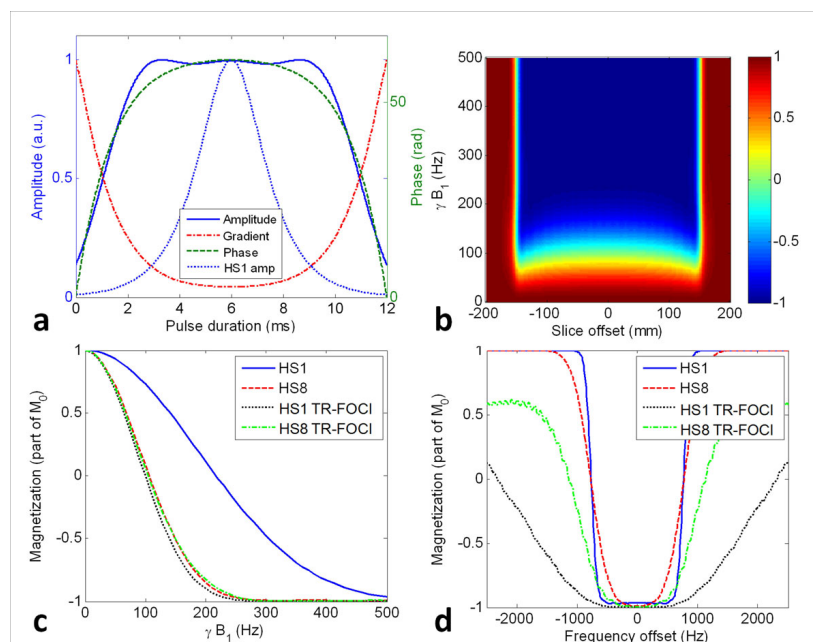
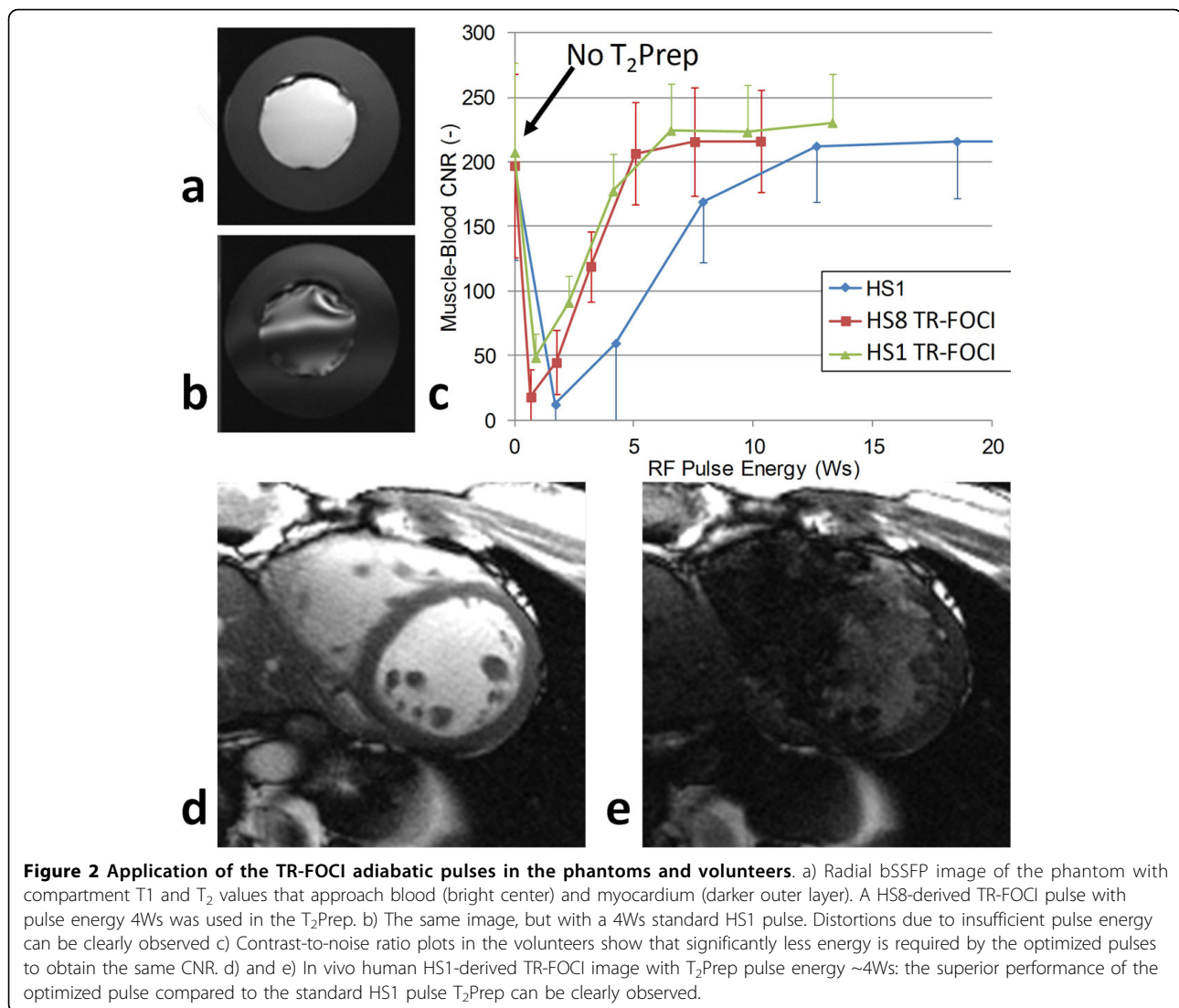


Figure 1 Performance of the tailored pulses. a) Example characteristics of the HS1-derived TR-FOCI pulse. Note that the optimized pulse is broad compared to the standard HS1 (dotted line). b) Slice-excitation profile of the same HS1-derived TR-FOCI pulse. Above a low pulse power of $\gamma B_1 \approx 200$ Hz, the profile has a very sharp transition. c) On-resonance inversion power requirements of the standard and TR-FOCI pulses. Once the HS1 pulse is optimized as a TR-FOCI pulse, it requires power similar to the standard HS8 pulse. d) Robustness of the same pulses to B_0 variability at pulse power $\gamma B_1 = 500$ Hz. While the poor original profile of the HS8 pulse is improved after optimization, it is especially the optimized HS1 that has improved robustness.

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3T, an adiabatic (robust to RF inhomogeneity ΔB_1) T₂ preparation (T₂Prep, Nezafat et al., MagnResonMed2006) can usually only be combined with balanced steady-state free precession (bSSFP) acquisitions with low nutation angles, or is played out only once every several heartbeats. Thus the design of T₂Prep adiabatic inversion pulses requires a compromise between pulse performance and the energy deposition. To overcome this SAR limitation on T₂Prep, we therefore numerically optimized two hyperbolic secant (HS_n; Silver et al. JMagnReson1984) RF pulses and tested their performance for T₂Prep refocusing in CMR at 3T.

Methods

A genetic algorithm based on Bloch equation simulations (Hurley et al., MagnResonMed2010) was used to numerically optimize standard adiabatic HS1 (higher power requirement and ΔB_1 robustness) and HS8 pulses (lower

power requirement and ΔB_1 robustness) to generate Time-Resampled Frequency-Offset-Corrected Inversion (TR-FOCI) pulses with a duration of 12 ms and an inversion band of 300 mm, which should easily cover the cardiac anatomy. The minimum energy requirements for satisfactory T₂Prep performance were assessed in agar-NiCl₂ phantoms and 3 healthy volunteers with a 2D radial bSSFP imaging sequence (nutation angle 70°, matrix 256², slice thickness 8 mm, lines per heartbeat 35) on a 3T clinical MR scanner (Skyra, Siemens) while monitoring SAR levels. The myocardium-to-blood CNR was calculated in both phantoms and volunteers and the minimum required pulse energy for constant CNR and absence of artifacts was compared.

Results

The optimized pulses demonstrated superior performance in the simulations compared to standard HS_n

pulses (Figure 1). The TR-FOCI pulses required 54% less power than the HS1 pulse to achieve artifact-free images and stable CNR (Figure 2), while images obtained with an HS8 pulse were never artifact-free. The optimized pulses needed roughly half the energy of the standard pulses, and the entire pulse sequence resulted in 20% less overall SAR deposition in the volunteers for artifact-free images with similar CNR as the original images.

Conclusions

We successfully implemented numerically optimized adiabatic pulses and demonstrated that they required less power for similar performance to HS_n pulses in a T₂Prep, which critically enables the use of CMR with bSSFP and T₂Prep at 3T.

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