HS8 SATURATION PULSE TRAIN FOR FIRST-PASS MYOCARDIAL PERFUSION IMAGING AT 7T

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Target audience: Basic scientists and clinicians interested in ultra-high field MRI or cardiac MRI.

Purpose: First-pass myocardial perfusion imaging is used clinically but would benefit from improved image quality. These improvements might be expected at 7T due to higher signal to noise ratio and longer T1 of the myocardium. But major implementation challenges at 7T are found owing to the large B0&B1 variations across the heart, low peak B1, and SAR restrictions that make uniform saturation extremely difficult to achieve. We propose a train of four HS8 pulses for saturation in first-pass myocardial perfusion imaging at 7T, and compare it with previously proposed solutions in simulation and in-vivo experiments. We also present the first series of human first-pass myocardial perfusion images at 7T.

Methods: The performance of five saturation methods was evaluated in Bloch simulations. Relaxation was ignored and perfect spoiling assumed. The five methods are BIR4 pulse[1], standard pulse train[2], tailored pulse train[1], hybrid pulse train[2], and HS8 pulse train. At each B1 levels, the maximum absolute normalized residual longitudinal magnetization were calculated in the B0 offset range of ±250 Hz.

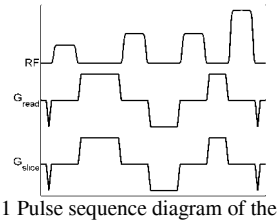

Fig.1 Pulse sequence diagram of the HS8 saturation pulse train.

The HS8 pulse train was optimized in the above B0 range for B1 between 150 and 400 Hz, with the relative RF power, defined as the power of the pulse train divided by that of a 1 ms rectangular pulse at the maximum amplitude, restricted to no more than 6. The optimized HS8 saturation pulse train (Fig.1) consists of four HS8 full-passage RF pulses[3] with gradient spoilers. Each HS8 pulse is 5ms duration and BW 1000 Hz. The peak amplitudes are 29%/47%/47%/84%, respectively, of the maximum amplitude available. The relative RF power is 4.9. Spoilers are 1/8/6/4/1 ms duration with peak amplitude 50 mT/m.

Eight male healthy volunteers (age 31±7, weight 77±8 kg) were recruited and scanned in accordance with local ethics on a whole-body 7T scanner (Siemens) with an 8-channel strip-line transceiver array.

All the saturation methods except BIR4 were implemented for in-vivo saturation of the mid-ventricular short-axis slice without contrast agent. In each breath hold, a first non-saturated image was collected then 8 s later one of the saturation methods was applied and a second image collected. The second image was pixel-by-pixel divided by the first image to calculate the normalized residual signal. Imaging parameters of the two images were: FOV 285×380 mm, matrix 144×192 iPAT 2, slice 8 mm, TE/TR 1.18/2.82 ms, nominal flip angle 10°, sequential ordering, ECG trigger delay 300 ms, TSAT 125 ms. The left ventricle myocardium was manually segmented into six segments, each of which was treated as an independent ROI. Mean (S_{mean}) and maximum (S_{max}) normalized residual signal were calculated in each ROI, and mean±(standard deviation) of S_{mean} and S_{max} were calculated over ROIs from all subjects.

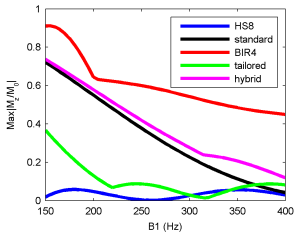

Fig.2 Maximum absolute normalized residual longitudinal magnetization in the B0 offset range of ±250 Hz as a function of B1, from numerical Bloch simulations.

A male volunteer (age 32, weight 80 kg) was scanned during the first pass of contrast agent (Dotarem). The HS8 pulse train was used for saturation. A single dose (0.05 mmol/kg, flow rate 6 ml/s) was injected with a power injector (Guerbet). 60 images were collected, one each heartbeat. The first image was not saturated.

saturation pulse train	S_{mean} (%)	S_{max} (%)
HS8	8.3±0.9	10.6±1.1
standard	19.3±7.1	29.8±12.5
tailored	10.9±4.2	18.7±6.5
hybrid	14.8±2.2	24.2±7.1

Table 1 Mean (S_{mean}) and maximum (S_{max}) normalized residual signal from in-vivo comparisons (each myocardial segment was treated as an independent ROI). Mean±(standard deviation) were calculated over ROIs from all subjects.

Results and discussion: The results from numerical simulations (Fig.2) and in-vivo comparisons (Table 1, Fig.3) show that the HS8 saturation pulse train effectively saturated the left ventricle short-axis slice, while saturation methods designed for 3T imaging were not as effective. This can be explained by the differences in the ranges of the B0&B1 variation targeted by these methods.

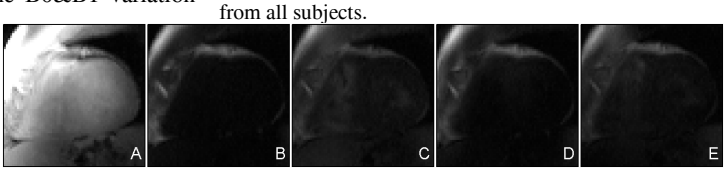

Fig.3 Short-axis slice: (A) non-saturated, saturated with (B) HS8, (C) standard, (D) tailored, (E) hybrid pulse train.

The images from the contrast scan (Fig.4) show that single-slice first-pass myocardial perfusion imaging is feasible for human at 7T. It should be noted that the imaging protocol used for this series was not optimized specifically for 7T, and the actual flip angle could be as low as 3°. The image quality in these first acquisitions is already comparable to that at 3T, supporting the great potential for perfusion imaging at 7T.

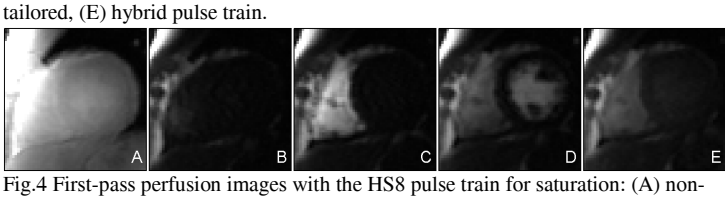

Fig.4 First-pass perfusion images with the HS8 pulse train for saturation: (A) non-saturated, (B) pre-contrast, (C) RV blood enhancement, (D) LV blood enhancement, (E) LV wall enhancement.

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References: 1. Sung K, *et al*. Magn Reson Med 2008; 60: 997–1002;
2. Kim D, *et al*. Magn Reson Med 2009; 62: 1368–1378;
3. Tannus A, *et al*. NMR Biomed 1997; 10 : 423–434.