Myocardial T2 imaging - Comparison of Free-Breathing T2-prepared Transient-State TrueFISP to Breath-Hold T2-prepared Segmented True FISP at 1.5T and 3T

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INTRODUCTION

BOLD imaging could allow myocardial perfusion to be assessed without the need for exogenous contrast agents, but previous gradient echo based implementations have been hampered by low SNR and susceptibility artifacts in some of the LV walls. Steady-state free precession techniques (SSFP) have gained broad success in cardiac applications due to their speed, high SNR and inherent flow compensation. Recent studies have demonstrated in animal models that SSFP techniques are highly sensitive to BOLD contrast in the heart, using either a T2 prepared segmented acquisition [1-2] or a steady state cine acquisition with long repetition time and large flip angle [3]. The first approach retains mixed T1 and proton density contrasts that must be removed for extracting the BOLD signal. The latter technique must control off-resonance and flow artifacts in order to be fully applicable in the human heart. By combining transient-state balanced SSFP with variable T2 preparation, we have previously shown maps of myocardial T2 in humans with adequate sensitivity to support cardiac clinical BOLD evaluations [4-5]. In this study, we compared at 1.5T and 3T, two variants of this SSFP technique that are compatible with breath-hold or respiratory-gated acquisitions, respectively. The goal was to evaluate their sensitivity and to determine the optimal field strength for clinical application of myocardial BOLD contrast imaging.

MATERIALS AND METHODS

An ECG-triggered T2 prepared TrueFISP sequence was combined with two different modes of image readout: (**a**) "single-shot" transient-state SSFP with half-Fourier readout and linear phase encoding (*TS-T2p-TFI*) [4-5] and (**b**) segmented SSFP with full-Fourier readout and centric phase encoding (*segm-T2p-TFI*). The first sequence mode produced an image within one heart cycle and was combined with PACE navigator or synchronized breathing to acquire respiratory-gated images every 5-7 seconds [5]. The second sequence mode produced a pair of images within a 20-25s breath-hold. T2-weighting was modulated in either case, by alternating the echo time of the T2 preparation block ($TE_{T2\text{-}prep}$) between two values selected for myocardial T2 relaxation measurement.

Thirteen healthy volunteers participated in the study: 9 subjects were scanned at 1.5T and 4 subjects at 3T (whole-body MR systems, Magnetom Avanto and Trio, Siemens Medical Solution). Series of repeated T2 measurements were collected using the two pulse sequence modes: NEX=10 image pairs with *TS-T2p-TFI* and NEX =3-5 image pairs with *segm-T2p-TFI*. All image data collected were short-axis images gated in end-systole (matrix: 128x128, FOV: 250-300 mm^2, slice: 6 mm, TE/TR:1.4/2.8ms at 1.5T or 1.6/3.2 ms at 3T). Parameters specific to *TS-T2p-TFI* were flip angle: 70° / SSFP stabilization: Kaiser-Bessel RF with 8 dummy pulses / $TE_{T2\text{-}prep}$: 2.6 ms and 56ms. Parameters specific to *segm-T2p-TFI* were flip angle: 30° / 11 segments / SSFP stabilization: $\alpha/2$ RF with 20 dummy pulses / $TE_{T2\text{-}prep}$: 25 ms and 56 or 86ms.

Data sets were fitted using a single exponential model. T2 maps were computed on a pixel-by-pixel basis. For each series, mean T2 were measured in the four walls of the left ventricle. Spatial variance across ROI and temporal standard deviations of T2 across repeated measurements were computed.

RESULTS AND DISCUSSION

Fig.1 shows T2-weighted images collected with the two methods on a subject at 1.5 Tesla and the corresponding computed T2 maps before and after averaging across repeated measurements collected over a similar period (Total Tacq = 2.5mins, NEX=10 with *PACE-TS-T2p-TFI* and NEX=5 with *Breath Hold-segm-T2p-TFI*). Myocardial T2 appears shorter with *segm-T2p-TFI* than with *TS-T2p-TFI*. Table 1 summarizes the results of all T2 measurements collected at 1.5T and 3T. Mean T2 values obtained at both field strengths with *TS-T2p-TFI* are in good agreement with myocardial T2 reported by others in humans [6-7]. Mean T2 values obtained with *segm-T2p-TFI* are shorter than reported values, both at 1.5T and at 3T. Finally, mean spatial and temporal variations in myocardial T2 are larger with segmented than with transient state sequence at 1.5T. The results of this study confirm the high performance previously shown of the respiratory-gated transient-state SSFP method for measuring myocardial T2 in humans [5]. Selection of the imaging parameters for *segm-T2p-TFI* was based on prior reports using T2-segmented SSFP for BOLD contrast evaluation [1-2]. Some of these parameters might explain the apparently poorer performance for T2 measurement (spatial σ and temporal σ) and the shorter detected T2 values. The longer minimal T2prep echo time and the lower flip angle reduce the overall T2 SNR. The longer SSFP stabilization period reduces T2 contrast at the start of the image readout, thereby lowering the apparent T2. The breath-held segmented acquisitions also suffer from greater difficulty in spatially registering repeated measurements for signal averaging. The preliminary results obtained at 3T showed with both methods an overall loss of performance (regional σ and temporal σ) that might be explained by enhanced off-resonance effects and a poorer performance of the nominal T2 magnetization preparation [6]. Significant improvements at this higher field strength are expected with access to local-based shimming and frequency adjustment, and the use of adiabatic pulses instead of MLEV composite pulses for the T2 preparation [8]. In conclusion, respiratory-gated T2prep transient state SSFP offers a robust method for myocardial T2 measurement with adequate accuracy to support BOLD imaging for clinical cardiac application. Further improvements, however, will be needed before the method can be translated to higher field strength.

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Table 1	1.5 Tesla		3 Tesla	
Myocardial T2	TS-T2p-TFI	Segm-T2p-TFI	TS-T2p-TFI	Segm-T2p-TFI
mean (ms)	56.7±3.6	43.5±4.8 †	56.3±8.2	29.9±9.7 †
spatial stdev (%)	7.3	12.5 *	14.5	19.2
temp. stdev (%)	2.9	6.0 †	5.4	6.1
†p<.001, *p<.05	(N=9)	(N=9)	(N=4)	(N=3)

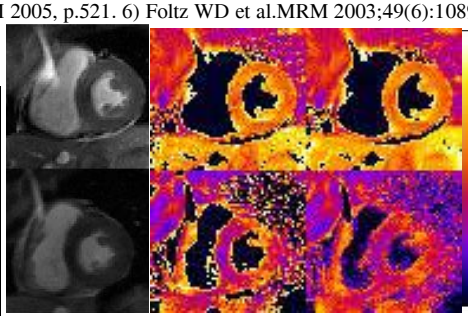

Fig1. **Top row** shows results with *TS-T2p-TFI* and the **bottom row** shows results with *segm-T2p-TFI* on a subject at 1.5T. T2-weighted TrueFISP images (**left**) and mean T2 maps computed from repeated measurements with NEX=1 (**center**) and with NEX = 10 (top-**right**) or 5 (bottom-**right**). (T2 map scale: 0-100ms).