Free-breathing T2-prepared Transient-state TrueFISP: Application to Myocardial T2 imaging

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INTRODUCTION

Myocardial blood oxygenation level-dependent (BOLD) MRI is a promising tool for noninvasively assessing the hemodynamic significance of suspected coronary artery disease [1, 2]. The method is based on T2 and T2* contrasts generated in the myocardium tissue during vasodilatory stimulation. In order to detect the relatively small T2 relaxation changes induced in vivo, a fast imaging technique with high T2 contrast-to-noise ratio and minimum sensitivity to cardiac and respiratory motions, is highly desirable. TrueFISP techniques (also denoted SSFP, balanced FFE or FIESTA) have recently been used in many cardiac applications due to their sub-second scan time, high signal-to-noise ratio and inherent flow compensation.

Combining T2 preparation pulse with transient-state TrueFISP imaging has shown promising results for generating maps of myocardial T2 in humans [3]. However, SNR of the T2 maps remained limited due to the small number of averages achievable within a breath-hold. In this study, we evaluated the use of 2D prospective acquisition correction technique (PACE) [4] for collecting large series of T2-weighted TrueFISP images in humans freely breathing. The goal was to improve the sensitivity of our technique for clinical application to myocardial BOLD contrast evaluation.

MATERIALS AND METHODS

An ECG-triggered transient-state TrueFISP pulse sequence with T2 preparation (T2prep-TrueFISP) [3] was implemented on a 1.5T whole-body MR system (Magnetom Sonata, Siemens Medical Solution, Erlangen, Germany) for the measurement of myocardial T2 relaxation. T2-weighting was controlled by changing the echo time of the T2 preparation block ($TE_{T2\text{-}prep}$) [3]. A 2D-PACE technique was used to monitor the subject's free breathing between scans and to trigger the image acquisition at end-systole during end-expiration. The technique consisted in acquiring a 2D navigator echo every 100ms from a cylindrical region positioned across the diaphragm (see shadowed area in Fig. 1.a) while the subject was freely breathing [4]. The time-series of navigator echoes processed real-time was used to determine the respiratory level with respect to the cardiac phase (see Fig. 1.b). The imaging sequence was triggered when the R-wave was detected and the measured diaphragm position fell into the acceptance window for end-expiration (double trigger). For the synchronized breathing image acquisitions (SBI), the volunteers were trained to breath between scans and to hold their breath at end expiration prior to each image acquisition. Time interval between scans was approx 6s for PACE and SBI acquisition modes.

Six healthy volunteers participated in this study approved by the instituion review board. Two sets of 21 T2-weighted images were collected using PACE and SBI methods in five subjects, while a single set of 61 T2-weighted images was collected in the last subject using only PACE. For each series, the first image was discarded and the other images were acquired at $TE_{T2\text{-}prep}$ alternating between 2.6ms and 55ms. All acquired images were single-shot short-axis images (TR/TE: 3.4/1.7 ms, matrix: 128x128, flip angle: 70, FOV: 250-300 mm x mm, slice thickness: 6 mm).

Data sets were fitted using a single exponential model. T2 maps were computed on a pixel-by-pixel basis and temporal variation maps (STD map) were computed from each time series of T2 maps (NEX=10 or 30). Then, for each series, mean T2 and temporal standard deviations of T2 were measured in the four walls of the left ventricle.

RESULTS AND DISCUSSION

Fig.2 shows T2-weighted True-FISP images collected in one subject at $TE_{T2\text{-}prep}$ of 2.6ms and 55ms. Fig.3 shows mean and STD maps from a series of repeated T2 measurements from another subject, using PACE and SBI. Notice the good agreement in mean and temporal variations of T2 between the two methods of respiratory gating. Myocardial T2 averaged across all six subjects was 53.9±5.4ms, a value which is very similar to myocardial T2 values reported by other groups in humans [1]. The mean temporal variation in myocardial T2 for all subjects was 1.62±0.74ms and 2.08±1.12ms, using PACE and SBI respectively.

The results of this study show excellent performance of the 2D-PACE method for cardiac and respiratory triggering of myocardial T2 measurements in humans. Temporal variations in myocardial T2 measured with this technique reached very similar values to those measured using a synchronized breathing protocol in a group of well trained subjects. Based on this level of physiological noise and based on prior animal studies of myocardial BOLD contrast using pharmacological stimulation, we can estimate the expected sensitivity of our technique for BOLD application. Given a baseline shot-to-shot T2 variations of 1.6ms in a ROI covering a LV wall, our technique should allow the detection of local T2 changes corresponding to one fold increase in myocardial perfusion. The great ease of use of the technique shows great promise for clinical application of myocardial T2 imaging. Only a short setup period is needed for properly positioning the navigator pulse prior to scanning and then the subject can be freely breathing while collecting repeated acquisitions, allowing for signal averaging. The repeatable measurements of myocardial T2 demonstrated in this study suggest the use of this technique as a robust and sensitive tool for myocardial BOLD contrast evaluation in the myocardium.

Reference

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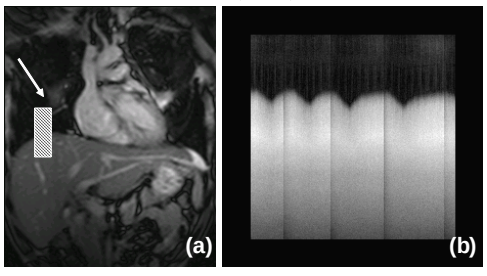

Fig. 1. PACE method. (a) position of the 2D selective navigator RF pulse. (b) Navigator echo time series showing the respiratory trace.

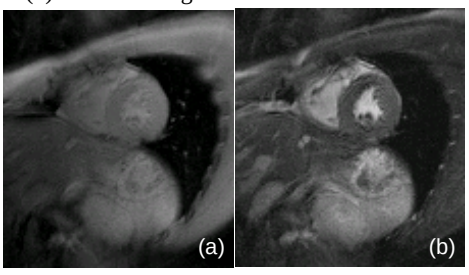

Fig. 2. T2-weighted TrueFISP images collected at $TE_{T2\text{-}prep}$ of 2.6ms (a) and 55ms (b).

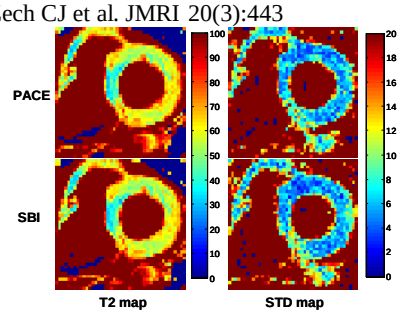

Fig. 3. T2 maps and stdev(T2) maps acquired from a subject during free-breathing with PACE and during synchronized breathing (SBI).