Free-Breathing Whole Heart CINE Imaging with Inversion Recovery Prepared SSFP Sequence: Feasibility for Myocardium Viability Assessment

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INTRODUCTION

Delayed enhancement (DE) MRI using inversion recovery (IR) sequence is an important tool for assessing myocardium viability. Typically an inversion time (TI) is set after an inversion pulse to null the normal myocardium thus enhance the contrast between the infarcted and normal myocardium. The image quality relies on the precise select of TI, which however varies subject by subject and changes over time during the contrast wash-out. Different methods have been proposed to solve this TI issue, including phase-sensitive inversion recovery (PSIR) [1] by acquiring extra reference image data and CINE IR[2] by acquiring multiple TIs. In this study, we developed a free-breathing 3D CINE IR sequence with continuous bSSFP data acquisition. Our preliminary results show the potential value of the proposed method.

MATERIALS AND METHODS

We implemented a novel pseudo-random undersampling strategy, CIrcular Cartesian UnderSampling (CIRCUS) to highly accelerate scan time[3]. CIRCUS integrates the nice features of radial/spiral trajectories with the randomization. MRI data were acquired from healthy volunteers on a 3.0T MR scanner (GE Medical Systems, Milwaukee, WI) with an 8-channel cardiac coil during free breathing. A 3D gradient-echo sequence with CIRCUS[3] (randomized golden-ratio radial sampling pattern) was applied, with FOV=320mm, TR/TE=3.6/1.4ms, FA=30°, BW= ±125kHz, slice thickness of 10mm, image matrix=256×160×16 (75% in k_y&k_z), and scan time of 150s. Inversion pulse was applied right after cardiac gating trigger was detected and data acquisition with bSSFP started as soon as possible (TI set to be minimum as 30 ms). We call it 1RR acquisition. To allow signal recover better, inversion pulse was also applied at every other cardiac cycle, named 2RR acquisition. Two acquisitions had the same scan time. bSSFP was continuously played before and after inversion pulses. Cardiac phases (each with a specific TI) were retrospectively reconstructed with a temporal resolution of 36 ms (views per segments=10). Retrospective respiratory gating was applied with efficiency of 50%. Data at each cardiac phase was undersampled (R=3~6) and was reconstructed using a multicoil CS reconstruction exploiting joint sparsity along temporal dimension [4,5].

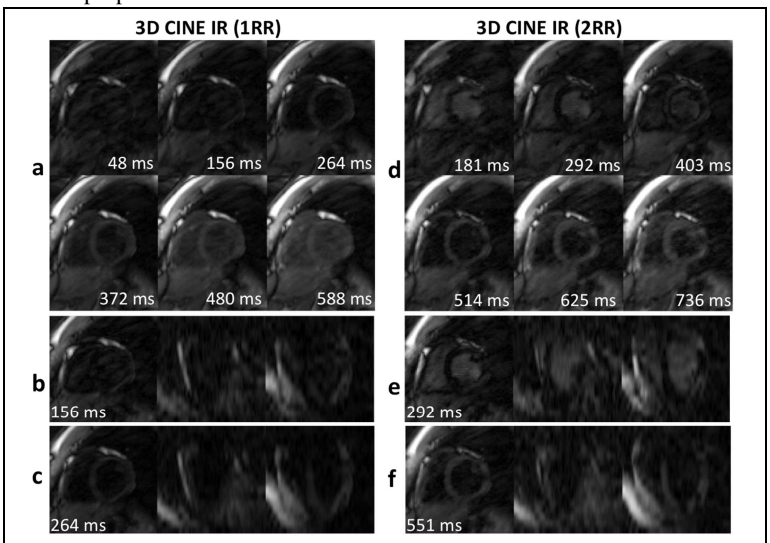

Fig.1 Representative images at six different TIs (cardiac phases) with **a)** 1RR and **d)** 2RR acquisition. The reformats of short-axis, two- and four-chamber views of the heart with nulled myocardium signal are showed in **b&e**, with nulled blood signal are showed in **c&f**. The myocardium and blood signal intensity change throughout the cardiac cycle (Fig.2a).

We simulated the T1 recovery of normal myocardium, blood and infarcted myocardium prep- and post-contrast. The T1/T2 values used for pre-contrast at 3T were the following: myocardium T1=1500ms, T2=50ms; blood T1=1550ms, T2=250ms. The T1/T2 values used for 15 minutes post Gd-DTPA injection at 3T are: myocardium T1=460ms, T2=50ms; blood T1=320ms, T2=250ms; infarct: T1=300, T2=50ms. TR=3.6ms, FA=30°. Inversion pulse was applied every 200 TRs for 1RR, every 400 TRs for 2RR.

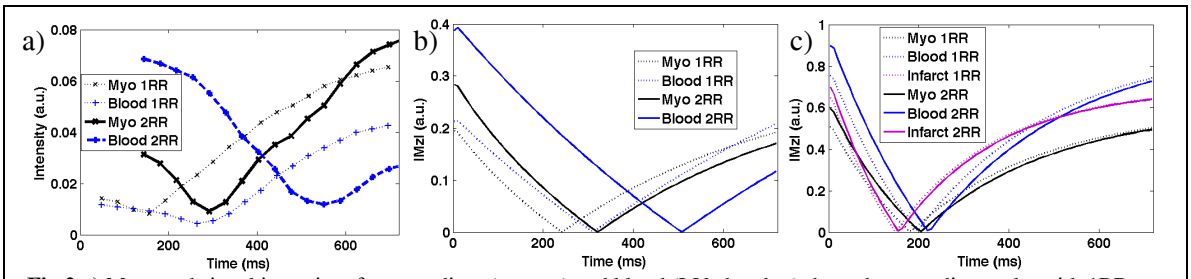

Fig.2 a) Measured signal intensity of myocardium (septum) and blood (LV chamber) throughout cardiac cycle, with 1RR and 2RR acquisitions. Simulated T1 recovery (absolute value) of **b)** pre-contrast and **c)** post-contrast tissues.

RESULTS & DISCUSSION

Fig.1a&d shows the CINE-IR images from a healthy subject with 1RR and 2RR acquisition. Reformatted images with nulled myocardium or blood are displayed in Fig1.b-c&e-f. The signal intensities of myocardium and blood change differently at two data sets, which is clearly seen in Fig.2a. The measured T1 recovery curves match well the simulated ones shown in Fig2.b (pre-contrast). Here the TIs are underestimated compared to (T1ln2), because the bSSFP readout causes a shorter T1 (referred as T1*). Fig.2c plots the T1 recovery curves for post-contrast myocardium, blood and infarct. The magnetization of infarct at the null of the normal myocardium with 2RR acquisition is higher than that with 1RR acquisition (0.130 vs 0.096). 2RR acquisition is expected to provide better delayed enhanced imaging of the infarct.

CONCLUSIONS

A free-breathing CINE-IR SSFP sequence was successfully implemented for imaging the whole heart with different inversion times. Our preliminary results demonstrated that the proposed method has great potential for myocardium viability assessment.

REFERENCES 1. Kellman P, et al, MRM 2002;47, p372. **2**. Goldfarb JW, et al, JMRI 2006;24, p66. **3**. Liu J, et al, ISMRM, p3796. **4**. Otazo R et al. MRM 2010 Sep;64(3):767-76. **5.** Feng L et al, MRM 2013; Jul;70(1):64-74.