Three dimensional black blood MRI with extensive cardiothoracic coverage: A feasibility study in healthy volunteers

T. D. Nguyen[1], K. Kawaji[2], P. Spincemaille[1], B. Reig[1], M. D. Cham[1], M. R. Prince[1], and Y. Wang[1]
[1]Radiology, Weill Cornell Medical College, New York, NY, United States, [2]Biomedical Engineering, Cornell University, Ithaca, NY, United States

INTRODUCTION

Black blood (BB) MRI is useful for morphologic assessment in cardiovascular diseases of the chest, including arrhythmogenic right ventricular dysplasia (1), myocardial iron deposition in thalassemia (2), left atrial appendage thrombus (3), aortic and coronary atherosclerosis (4,5), pulmonary vascular lesions (6), and congenital heart disease. Cardiothoracic BB imaging is commonly performed using a breath-hold double inversion recovery (DIR) 2D fast spin echo sequence, which has limited volumetric coverage and requires substantial patient cooperation and operator skill in planning imaging planes due to the complex anatomy of the heart and the great vessels. While a 3D BB imaging sequence of the whole heart and chest similar to the whole-heart coronary artery imaging approach (7,8) is highly desirable, commonly used BB preparation techniques such as DIR (9) and spatial presaturation of upstream blood (10) rely on blood flow and do not work well in large imaging volumes. Recently, T2prep inversion recovery (T2IR) has been proposed to provide flow-independent black blood contrast for 2D imaging of the heart, carotid (11) and peripheral (12) arteries. The purpose of this study is to develop a free-breathing and SNR-efficient 3D T2IR prepared balanced SSFP sequence and investigate its feasibility for BB imaging of the whole chest within a reasonable scan time.

METHODS

Figure 1 shows the schematic of our free-breathing 3D T2IR-SSFP imaging sequence. After the cardiac trigger, flow-insensitive T2IR preparation is played out with a T2PREP time and an inversion time (TI) chosen to null the blood signal while maximizing the vessel wall signal (12) at the beginning of the SSFP data acquisition during diastole. A cylindrical diaphragmatic navigator (NAV) is used to monitor respiratory motion, followed by a spectrally selective fat saturation (FATSAT) pulse, and a 6 Kaiser-Bessel ramp-up RF excitation to provide a balance between minimizing off-resonance oscillations in subsequent data sampling and providing accurate motion information for navigator gating. An efficient phase-ordered automatic window selection (PAWS) real-time navigator gating algorithm (13) was used, which automatically selects a gating window at the most likely diaphragm position even in the case of respiratory drift and reduces residual motion artifacts within the gating window through view ordering.

Five healthy volunteers (mean age of 33 ± 7 years) were scanned at 1.5T (GE HDxt 15.0) using the following typical imaging parameter: TR = 3.4 ms, TE = 1.3 ms, flip angle = 60°, readout bandwidth = ±62.5 kHz, sagittal FOV = 30 cm, partial phase FOV factor = 0.75-1, matrix size = 256x256, slice thickness = 2.4 mm (interpolated to 1.2 mm), number of slices = 64, T2PREP time = 100 ms, navigator gating window = 5 mm. A 2D scout scan was used to estimate TI for optimal blood suppression prior to high-resolution 3D imaging. Left ventricular (LV) myocardium SNR and myocardium-to-LV lumen CNR were measured to assess image quality.

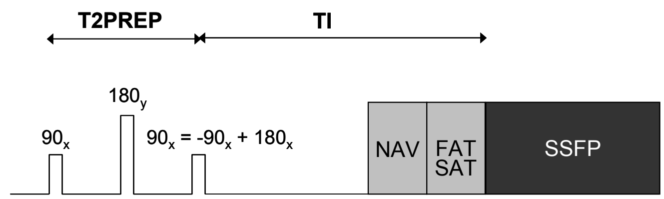

Fig.1. 3D T2IR-SSFP sequence for free-breathing BB imaging of the whole chest. Note that all T2IR pulses are spatially non-selective and the -90_x tip-up of the T2prep sequence and the 180_x inversion pulse can be combined as shown.

RESULTS

All scans were completed successfully. The average scan time and navigator efficiency was 523 ± 99 sec and 49 ± 10%, respectively. Figure 2 shows typical BB images of the thorax reformatted into conventional cardiac and aortic arch views, demonstrating excellent blood suppression and good image quality within a large FOV encompassing heart and nearly the entire aorta. Note that the flow-insensitive T2IR preparation provided effective blood suppression near the cardiac apex and in the long-axis views where slow or in-plane blood flow can be problematic. Myocardium SNR and myocardium-to-lumen CNR was 43 ± 15 and 35 ± 13, respectively.

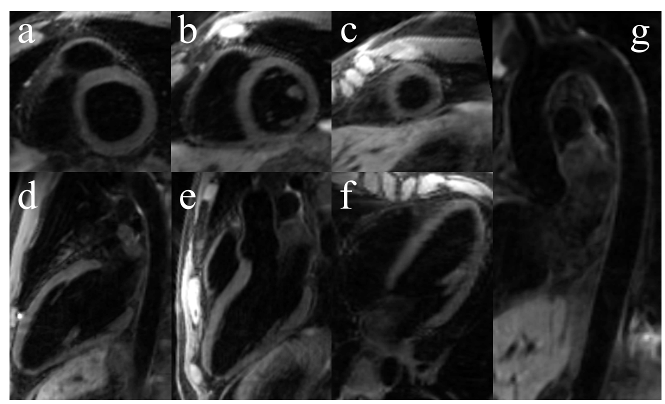

Fig.2. Reformatted cardiothoracic BB images obtained during free breathing: a) basal, b) mid, c) apical cardiac short-axis view, d) two-chamber, e) three-chamber, f) four-chamber cardiac view, and g) thoracic aortic wall.

DISCUSSION

These preliminary data in five healthy volunteers demonstrate the feasibility of 3D BB imaging of the entire chest in under 10 min without breath holding using the developed T2IR-SSFP sequence. Besides providing excellent global blood suppression and volumetric coverage with good SNR and CNR, this sequence may be instrumental in disseminating cardiovascular MRI technology to sites with less experienced operators. Further reduction in scan time is possible with the use of parallel imaging. Future work will focus on the evaluation of this technique in diseased patients.

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