Dark blood fat-water separated cardiac imaging improves delineation of right ventricular myocardium

Peter Kellman[1], Diego Hernando[2], Saurabh Shah[3], Zhi-Pei Liang[2], Andrew E. Arai[1]

[1]Laboratory of Cardiac Energetics, National Heart Lung and Blood Institute, NIH, DHHS, Bethesda, Maryland 20892 USA
[2]University of Illinois, Urbana, IL, United States
[3]Siemens Medical Solutions, Chicago, IL, United States

INTRODUCTION

Fat-water imaging in the heart [1-4] is important for detection of intramyocardial fat and characterizing fibro-fatty infiltration seen in ARVD and chronic MI. It is also useful in characterizing fatty tumors and delineating epicardial and/or pericardial fat. Multi-echo GRE acquisitions provide T1-weighed contrast between the myocardium and blood pool, however, it is often difficult to delineate fine structures such as the RV myocardial wall due to limited contrast. Double inversion recovery (DIR) magnetization preparation is frequently used with turbo-spin echo (TSE) sequences to provide dark blood contrast. A DIR dark blood prepared multi-echo GRE protocol is proposed for cardiac fat-water separated imaging to improve delineation of myocardial structures.

METHODS

A multi-echo GRE sequence using gradient flyback for monopolar readout was used to acquire 4 echoes. The VARPRO-GRAPHCUT joint water/fat estimation method [5] was used to reconstruct fat and water images. This method provides good noise performance and robustness to significant field inhomogeneities. ECG triggering was used to acquire a mid-diastolic phase image in a segmented fashion. The DIR preparation used adiabatic inversion pulses. Imaging parameters using the 1.5T Siemens widebore Espree scanner were: bandwidth=977 Hz/pixel, TE=1.64, 4.17, 6.7, and 9.23 ms, TR=11.24 ms, excitation flip angle=10°, matrix=256x150, 15 PE lines per segment (169 ms), FOV=360x270 mm^2, slice thickness≈8 mm, breath-hold duration = 12 heartbeats including 2 discarded, and 32 channel cardiac array. For comparison, bright blood, multi-echo GRE segmented cine fat/water separated protocol used a 20° flip angle, and rate 2 parallel imaging. Multi-echo GRE, single phase diastolic images without DIR preparation were also acquired for comparison. Triggering every RR interval was compared with triggering each 2 RR's was used. Parallel imaging with rate = 2 was used with 2-RR triggering to maintain a reasonable breath-hold duration.

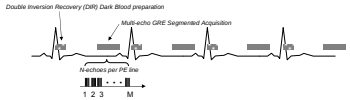

Figure 1. Sequence diagram for single diastolic imaging with DIR dark blood preparation (shown using single RR triggering).

Images were acquired for short axis slices using both dark blood and bright blood fat water imaging protocols in patients that provided written informed consent. Magnetization vs readout flip angle for fat and myocardium was simulated (Fig 2) for bright blood cine protocol using steady state formulation (continuous RF) and for dark blood protocol modeling approach to steady state. Low fat-to-myocardial contrast is desirable for accurate fat quantification [6]. The DB protocol at 10° acquired during approach to steady state reduced the T1-weighting as desired compared to the cine protocol without sacrificing SNR. The T1 contrast for blood (not simulated) is predominately due to inflow of new spins.

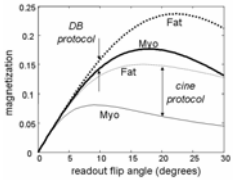

Figure 2. Simulated magnetization vs readout flip angle.

RESULTS

Example images (Fig 3) for a study to rule out ARVD (negative case) compare the bright blood cine with the dark blood protocols. The thin RV myocardium is difficult to discern in the bright blood images due to lack of sufficient contrast between RV myocardium and blood. However, the RV free wall is well depicted in the dark blood prepared images. In this example, the measured T1-weighted contrast of the myocardium-to-blood (water image septal region) was 1:1.5, whereas for the dark blood protocol the contrast was greater then 4:1.

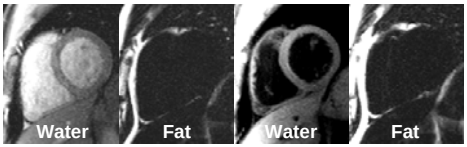

Figure 3. Water and fat separated images for short axis slice using bright blood cine protocol (left), and DIR (dark blood) prepared protocol (right) illustrating improved myocardium-blood pool contrast and, therefore, improved ability to delineate the thin walled RV myocardium.

Example images (Fig 4) comparing single phase diastolic imaging using multi-echo GRE fat waters separated imaging with and without dark blood preparation. Single phase bright blood images at low excitation flip angle have low T1 contrast between myocardium and blood. Figure 5 compares single phase diastolic images with dark blood preparation applied every R-R (left) with 2 R-R intervals (right). The image quality is comparable between these 2 protocols.

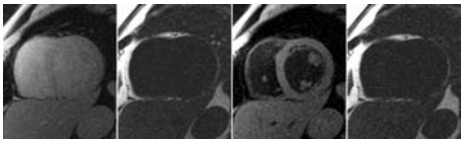

Figure 4. Comparison of single phase diastolic water and fat images without DB prep (left) and with DB prep (right).

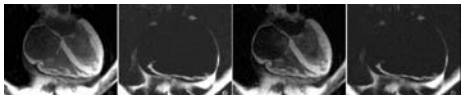

Figure 5. Comparison of single phase diastolic water and fat images using RR=1 triggering (left) and using RR=2 triggering and parallel imaging (right).

DISCUSSION

A dark blood prepared fat/water separated imaging protocol has been developed which provides improved delineation of the myocardium. This should improve the ability to discern fatty infiltration of the RV which has potential in the diagnosis of ARVD. The proposed approach does inherit the limitations of DIR dark blood preparation method, namely, it can lead to posterior wall signal loss due to cardiac motion at higher heart rates or in cases where the timing is not set properly and potential bright rim artifacts due to stagnant blood. With this approach, a reduction in excitation flip angle is possible which reduces the T1-weighting thereby improving fat fraction estimates.

REFERENCES

1. Reeder SB, et al. JMRI. 2005 Jul;22(1):44-52.
2. Kellman P, et al. MRM. 2009 Jan; 61:215–221.
3. Goldfarb JW. MRM. 2008 Sep;60(3):503-9.
4. Vigen KK, et al. Proc. ISMRM. 17 (2009) 2775
5. Hernando D, et al., MRM 2009 (In press).
6. Liu, CY, et al. MRM. 2007 Aug;58(2):354-64.