PDF poster available at: http://dir.nhlbi.nih.gov/kellman

Multi-echo Dixon Fat and Water Separation Method for Detecting Fibro-fatty Infiltration in the Myocardium

Peter Kellman[1], Diego Hernando[2], Zhi-Pei Liang[2], Saurabh Shah[3], Sven Zuehlszorff[3], Renate Jerecic[3], Christine Mancini[1], Andrew E. Arai[1]

[1]Laboratory of Cardiac Energetics, NHLBI, NIH, Bethesda, MD 20892 USA, [2]Univ. of Illinois, Urbana, IL, USA, [3]Siemens Medical Solutions, Chicago, IL, USA

INTRODUCTION

The ability of MRI to discriminate between water and fat is important in tissue characterization. It has been shown that fibrofatty infiltration of the myocardium is associated with sudden death and, therefore, non-invasive detection could have high prognostic value. Conventional approaches for fat and water discrimination based on fat suppression are commonly used to characterize masses, however, have reduced ability to characterize fatty infiltration due to the poor contrast of microscopic fat and partial volume effects.

Multi-echo Dixon methods [1,2] for fat and water separation provide a sensitive means of detecting small concentrations of fat with improved contrast. These methods have been applied to the detection of fibro-fatty infiltration observed in chronic myocardial infarction (MI) as well cases of suspected arrhythmogenic right ventricular cardiomyopathy (ARVC). In the present study, fat and water separation has been implemented both pre-contrast as well as applied to late enhancement using a multi-echo phase sensitive inversion recovery gradient recalled echo (PSIR-GRE) sequence.

METHODS

It was hypothesized that the multi-echo Dixon method of fat-water imaging could be used to detect intramyocardial fat. Multi-echo GRE fat-water imaging was performed on 34 patients with either known or suspected coronary artery disease, or with suspicion of intramyocardial fat.

A multi-echo GRE sequence was implemented with fat and water separation using a multi-point Dixon reconstruction method. Late enhancement imaging used a multi-echo IR-GRE which additionally incorporated phase sensitive reconstruction [3]. The PSIR-GRE sequence acquires a proton density reference on alternate heartbeats which was used to jointly estimate a fieldmap and fat and water separation matrix that is applied to the inversion-recovery (IR) images. The VARPRO method [2] was used to robustly estimate the fieldmap in the presence of field inhomogeneity. The imaging sequence (Fig. 1) was ECG triggered, with 2 R-R intervals between inversions, and used an echo-train readout with 4 echoes with flyback for monopolar readout. The echo-train readout was used to increase the acquisition efficiency and thereby maintain acceptable breath-hold duration. The effective number of signal averages (NSA) for the parameters used was calculated from the Cramer-Rao lower bound [4]. Typical parameters for imaging with the Siemens ESPREE 1.5T scanner were: bandwidth=977 Hz/pixel, TE= 1.64, 4.17, 6.7, and 9.23 ms, TR=11.2 ms, flip angle=20-25°, image matrix=256x126, views-per-segment=19, breath-hold duration=16 heartbeats including 2 discarded.

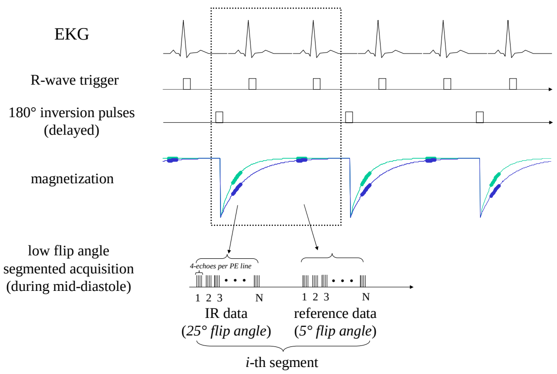

Figure 1. Pulse sequence diagram for ECG triggered, segmented *k*-space acquisition of IR and reference images using low flip angle readouts. Data for IR and reference images are collected alternately every other heartbeat.

RESULTS

The technique was applied successfully in all 34 patients. There were 17 cases with MI (2 acute/15 chronic) of which 4 cases with chronic MI exhibited fatty infiltration [5]. Water and fat separated images for a case with fatty infiltration in chronic anteroseptal MI are shown in Fig. 2 for both pre-contrast (a),(b) and PSIR late enhancement (c),(d).

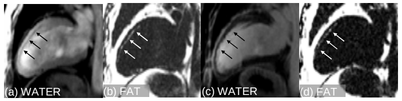

Figure 2. Water and fat separated images using multi-echo Dixon method for patient with chronic MI showing fatty infiltration. (a),(b) pre-contrast and (c),(d) PSIR late enhancement.

There were 4 cases of atypical late enhancement of which 2 cases (Figures 3 and 4) had intramyocardial fatty infiltration (1 case confirmed by biopsy of the septum). In these cases, the water and fat separated images acquired in a single breath-hold, are compared with the conventional approach using dark-blood prepared TSE acquired with and without chemical shift fat saturation in 2 separate breath-holds. One patient with non-ischemic cardiomyopathy and fibrosis (Fig. 3) exhibited intramyocardial fat clearly evident in the fat separated image (Fig. 3d) but difficult to discern in the conventional fat suppressed dark-blood TSE image (Fig. 3b). Fat is observed (see arrows) in endocardial regions of both LV and RV myocardium. A second patient exhibited intramyocardial fat in the septum and anterior sector (longer arrow) of LV myocardium which is more readily discerned in the fat separated image (Fig. 4d) which has positive contrast than by comparison of TSE images acquired with and without saturation (Fig. 4(a),(b)).

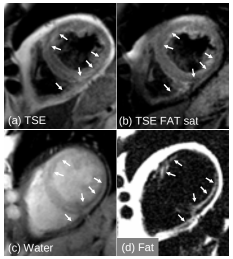

Figure 3. Patient with non-ischemic cardiomyopathy. Intramyocardial fat clearly evident in the fat separated image (d) which is difficult to discern in conventional fat suppressed image (b).

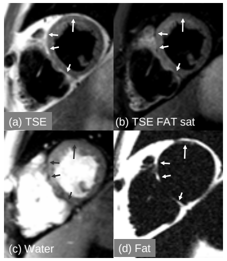

Figure 4. Second patient with intramyocardial fat clearly evident in the fat separated image (d) which is difficult to discern in conventional fat suppressed image (b).

Water and fat separated PSIR late enhancement images for 2 patients with chronic MI are shown in Figures 4 and 5. Fatty infiltration of the MI region (Fig. 4) is evident in 1 of the patients. The overall infarct image quality is quite good and comparable to conventional late enhancement without water and fat separation, with the water separated image yielding the same diagnostic quality as the conventional late enhancement image in all of the cases.

One patient had a large lipoma (Fig. 6) and another had a region with lipotamous hypertrophy of the interatrial septum. While fat suppression of the epicardial fat and the lipoma mass (Fig 6b) was excellent, the water and fat separated images (Fig. 6(c) and (d)) had even greater contrast.

Epicardial fat was readily distinguished from myocardium in all cases.

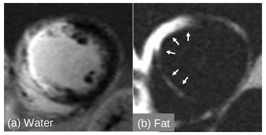

Figure 5. PSIR water and fat separated late enhancement images acquired in a single breath-hold for patient with chronic MI showing fibro-fatty infiltration (a) water, and (b) fat.

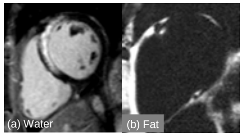

Figure 6. PSIR water and fat separated late enhancement images acquired in a single breath-hold for patient with chronic MI for case without fibro-fatty infiltration (a) water, and (b) fat.

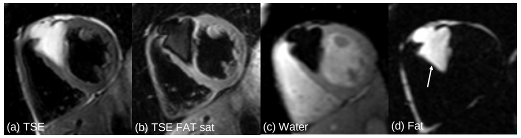

Figure 7. Pre-contrast images for patient with large anteroseptal lipoma (a) TSE without fat saturation, and (b) TSE with fat saturation, acquired in 2 separate breath-holds, and (c) water, and (d) fat separated images acquired in a single breath-hold using a multi-echo Dixon approach.

CONCLUSIONS

The multi-echo Dixon method for fat and water separation provides a sensitive means of detecting intramyocardial fat with positive signal contrast, thereby achieving a high degree of confidence, whereas conventional fat suppression is often difficult to interpret due to fluctuations in the water signal. The proposed water and fat separation method is combined simultaneously with late enhancement imaging to provide positive correlation between fibrosis and fat. The proposed VARPRO approach to multi-echo Dixon water and fat separation is robust for clinical application to cardiac imaging. Using the proposed method fibro-fatty infiltration has been observed in chronic MI as well as cases of suspected ARVC. This technique could be used to assess the prognostic value of the presence and amount of myocardial fat infiltration.

DISCUSSION

The presence of intramyocardial fat in diseases such as ARVC may form a substrate for reentrant ventricular arrhythmias leading to sudden death [6,7]. Analysis of autopsies has shown that fibrofatty infiltration into the myocardium was more predictive of sudden death than simply fatty infiltration [6]. However due to the subjectivity of interpreting the presence of intramyocardial fat using conventional fat suppression methods, MRI fibrofatty infiltration is not part of the current accepted Task Force criteria [7]. The proposed multi-echo Dixon method may be helpful in diagnosis of patients with ARVC due to the improved fat-myocardial contrast.

REFERENCES

1. Reeder SB, et al., MRM 2005 Sep;54(3):636-44.
2. Hernando D, et al., MRM, In Press.
3. Kellman P, et al., MRM 2002 Feb;47(2):372-83.
4. Pineda AR, et al., MRM 2005 Sep;54(3):625-35.
5. Goldfarb JW, et al., MRM 2007 May;57(5):828-34.
6. Bluemke DA, et al., Cardiology. 2003;99(3):153-62.
7. Burke AP, et al., Circulation. 1998;97(16):1571-80.