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

Peter Kellman1, Diego Hernando2, Zhi-Pei Liang2, Saurabh Shah3, Sven Zuehlke, Renate Jeremic3, Christine Mancini1, Andrew E. Arai1
1Laboratory of Cardiac Energetics, NHLBI, NIH, Bethesda, MD 20892 USA, 2Univ. of Illinois, Urbana, IL, USA, 3Siemens 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 as 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 and RF saturation for mono-echo 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 was calculated from the Cramer-Rao lower bound [4].

Typical parameters for imaging with the Siemens ESPEE 1.5T scanner were: bandwidth=0.7, Pixel TE=1.64, FA=17, 6.7, and 9.23 ms, TR=11.2 ms, flip angle=25°, image matrix=256x126, views-per-segment=19, breath-hold duration=16 heartbeats including 2 discarded.

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).

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 T1 image (Fig. 3b). Fat is observed (see arrow) 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. 4a,b). 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.

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

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