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

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Introduction

The ability of MRI to discriminate between water and fat is important in tissue characterization. Conventional approaches to 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 MI [3] as well cases of suspected ARVC/D [4]. 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 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 [5]. 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 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 [6]. 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.

Results

There were 17 cases with MI (2 acute/15 chronic) of which 4 cases with chronic MI exhibited fatty infiltration. Water and fat separated images for a case with fatty infiltration in chronic anteroseptal MI are shown in Fig. 1 for both pre-contrast (a),(b) and PSIR late enhancement (c),(d). There were 4 cases of atypical late enhancement of which 2 cases had intramyocardial fatty infiltration (1 case confirmed by biopsy of the septum). One patient with non-ischemic cardiomyopathy and fibrosis exhibited intramyocardial fat clearly evident in the fat separated image (Fig 2a) but difficult to discern in the conventional fat suppressed dark-blood TSE image (Fig 2b). One patient had a large lipoma (Fig. 3) and another had a region with lipotamous hypertrophy of the interatrial septum. Epicardial fat was readily distinguished from myocardium in all cases.

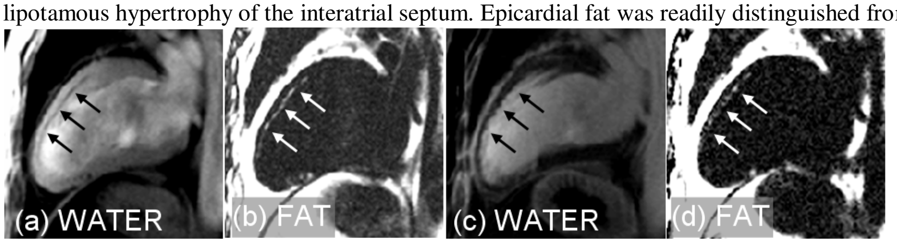

Fig. 1. Water and fat separated images for patient with chronic MI showing fatty infiltration. (a),(b) pre-contrast and (c),(d) PSIR late enhancement.

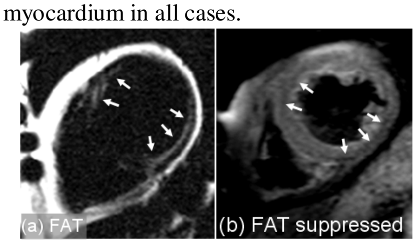

Fig. 2. Intramyocardial fat clearly evident in fat separated image (a) which is difficult to discern in conventional fat suppressed image (b).

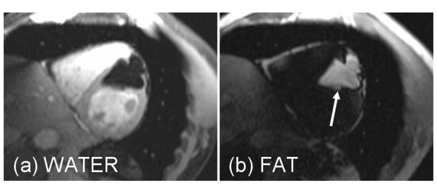

Fig. 3 Water and fat separated pre-contrast images for patient with large anteroseptal lipoma.

Discussion

The proposed approach can characterize intramyocardial fat before or after contrast administration. A benefit of using late enhancement with fat-water separation is the ability to display contrast enhanced myocardial fibrosis in the water image and fatty infiltration in the fat image, both acquired simultaneously. Initial experience indicates a much higher contrast and sensitivity than conventional fat suppression, or T1 measurement methods. The fat separated image has positive contrast against a noise background providing greater confidence in detection than conventional fat suppression which is often difficult to discriminate from fluctuations in the water signal. The phase sensitive reconstruction is insensitive to inversion time (TI) which is particularly important when assessing atypical late enhancement with patchy appearance. The proposed method has the additional benefit of using a single breath-hold to produce fat and water images, thereby improving the workflow and ensuring spatial registration. The VARPRO method provided robust fieldmap estimates.

Use of multi-echo Dixon fat-water separation with 3 echoes at non-optimum TE's may be ill-conditioned and not achieve the full SNR gain (effective number of signal averages). Although optimum TE's [6] were not achievable using monopolar readout, the 4 echo implementation is very robust and achieved within 5% of the optimum expected SNR (4 effective averages) almost completely independent of the fat/water ratio.

The presence of intramyocardial fat in diseases such as ARVC/D may form a substrate for reentrant ventricular arrhythmias leading to sudden death [4]. 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. The proposed multi-echo Dixon method may be helpful in patients with ARVC/D due to the improved fat-myocardial contrast.

References

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