Free-breathing, single shot fat-water separated cardiac imaging with motion corrected averaging

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Introduction

Fat-water imaging in the heart [1-4] is important for detection of intramyocardial fat and characterizing fibrofatty infiltration seen in ARVD and chronic MI. It is also useful in characterizing fatty tumors and delineating epicardial and/or pericardial fat. Cardiac imaging using multi-echo sequences is typically performed using a segmented acquisition which may be difficult for patients that are unable to hold their breath or problematic in cases of arrhythmia. A free-breathing, single shot fat-water separated imaging protocol was developed using parallel imaging acceleration. Motion corrected averaging of multiple free-breathing repetitions was employed to further improve image quality.

Methods

A 2 echo GRE sequence using gradient flyback for monopolar readout was used to acquire in and out of phase echoes. The VARPRO-GRAPHCUT joint water/fat estimation method [5] was adapted for 2-point (in-phase/out-of-phase) acquisitions by explicitly including the in-phase constraint. This method provides good practical noise performance and robustness to significant field inhomogeneities. ECG triggering was used to acquire a single-shot mid-diastolic phase image repetitively for several consecutive heartbeats. Imaging parameters using the 1.5T Siemens widebore Espree scanner were: parallel imaging rate 3 using GRAPPA with separate reference line acquisition (32 lines), 32 channel cardiac array, bandwidth = 965 Hz/pixel, TE = 2.38 and 4.76 ms, TR = 5.9 ms, readout flip angle = 20°, matrix = 192x108, single shot duration = 213 ms, FOV = 360x270 mm^2, slice thickness = 6 mm, no. repetitions = 8. An optional inversion recovery (IR) preparation could be selected for late enhancement imaging. Following image reconstruction, a non-rigid image registration was used to correct respiratory motion and a "selective" averaging [6,7] was used which selected the "closest" 50% of images to average, thereby mitigating against thru-plane motion and providing protection against significant RR-variations.

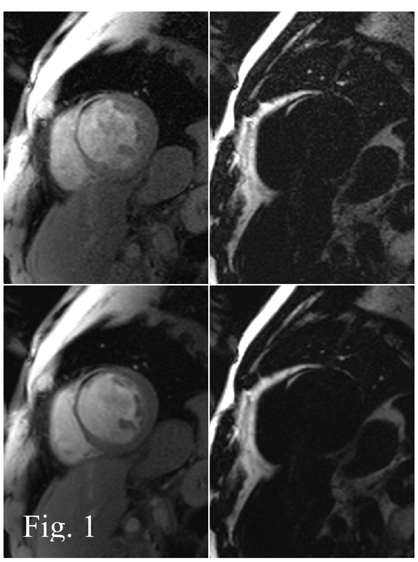
Images were acquired for a single short axis slice using the single shot fat water imaging protocol in patients that provided written informed consent. Image quality was scored for 31 subjects graded qualitatively on a 5 point scale where 4 = excellent image quality, SNR, and freedom from artifacts; 3 = Good; 2 = Fair – some issues with image quality, artifacts but readable with confidence; 1 = Poor – significant artifacts but could diagnose some areas; 0 = Nondiagnostic. Organs and tissues were assessed for qualitatively appropriate fat/water characterization. We assumed subcutaneous fat, epicardial/mediastinal fat, and subdiaphragmatic fat should be predominantly bright on fat images but dark on water images. Skeletal muscle, myocardium, blood, liver, and spleen were assumed should be predominantly bright on water images and dark on fat images.

Results

Example images (Fig. 1,2) for a patient with chronic MI exhibiting fatty infiltration show the improvement in quality following respiratory motion corrected averaging. Overall, image quality averaged 3.42 +/- 0.85 on water images which was statistically better than the image quality of fat images 3.10 +/- 0.83. All images were diagnostic quality. Tissue characterization of fat vs water was correct in 30 of 31 subjects with the exception that there were 6 significant swaps in the chest wall or part of the chest wall.

Discussion

A rapid fat/water separated imaging protocol has been developed for free-breathing cardiac applications for cases where patients have difficulty breath-holding or have significant arrhythmias. A limitation of the 2 echo approach is the lack of R2* estimation which can lead to degraded separation.



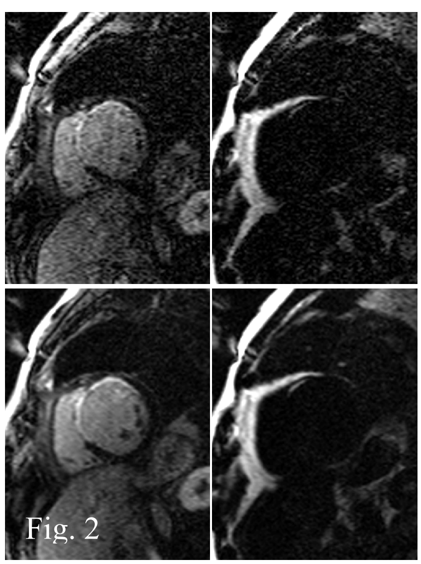


Figure 1. Water (left) and fat (right) images of patient with fibro-fatty infiltration of anterior chronic MI acquired free-breathing using single-shot, 2 echo method for single measurement (top) and with motion corrected selected averaging of 4 out of 8 images (bottom).

Figure 2. Late enhancement images using IR-GRE protocol showing water (left) and fat (right) separated images for chronic MI patient of Fig 1. Single measurement (top) and with motion corrected selected averaging of 4 out of 8 images (bottom).Zhi

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