Rapid, multi-slice fat water separated imaging for mapping body fat

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Introduction

Whole body mapping of fat using MRI offers the advantages of rapid and precise determination of fat content as well as compartment (e.g. visceral, subcutaneous) which is important for risk stratification [1]. Fat/water signal fraction may be estimated using multi-echo approaches [2,3]. A protocol for rapid multi-slice fat water separated imaging is proposed which combines a 3-echo GRE acquisition and parallel imaging to scan 4 slices per second. This protocol may be performed during free breathing. A recently developed joint estimation method for water/fat separation and field map is able to perform robustly in the presence of large B0 field inhomogeneities [3].

Methods

A multi-echo GRE sequence using gradient flyback for monopolar readout was used to acquire 3 echoes for each phase encode. The joint water/fat estimation method [3] based on graph cuts optimization was used to estimate both the field map and reconstruct fat and water images. This method provides good noise performance and robustness to significant field inhomogeneities. Images were acquired single-shot. Imaging parameters using the 1.5T Siemens Avanto scanner were: parallel imaging rate 3 using GRAPPA with separate reference line acquisition, 32 channel cardiac array, bandwidth=1184 Hz/pixel, TE=1.33, 3.35, and 5.37 ms, TR=6.71 ms, readout flip angle=20°, matrix=192x108, single shot duration=242 ms, FOV=300x225 mm^2, slice thickness=6 mm. Auto-calibration signals (ACS) were acquired separately for each slice using a single shot acquisition at the start of the scan requiring 215 ms per slice (32 lines). The imaging volume was prescribed to cover the full chest volume which was limited in this study by the cardiac coils. For example, 300 mm was acquired with 48 axial slices requiring a total of 22 s (12 s imaging and 10 s auto-calibration).

The protocol was evaluated in 5 subjects (216 slices) with written informed consent. The performance of the fat water classification was scored for all slices. Image quality was 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 (2=correct classification, 1=mostly correct, 0=incorrect). 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, spleen, and kidneys were assumed should be predominantly bright on water images and dark on fat images.

Results

The performance of fat water classification was excellent. A total of 216 slices were evaluated. Overall image quality was good in all subjects and all slices (mean=3). Misclassification errors were detected in 4 of 216 slices. All errors were limited to portions of the subcutaneous fat or skeletal muscle. The method correctly classified fat and water in the major organs and had greater than 99% correct classification on a volume basis of body fat. The average score for fat/water classification of the major internal organs was mean=2 consistent with correct classification. Likewise, intra-abdominal and pericardial/mediastinal fat were correctly classified. Example images (Fig. 1) are shown for 1 subject displaying every 6-th image across the chest and abdomen in the field of view (Fig 2 shows coronal localizer).

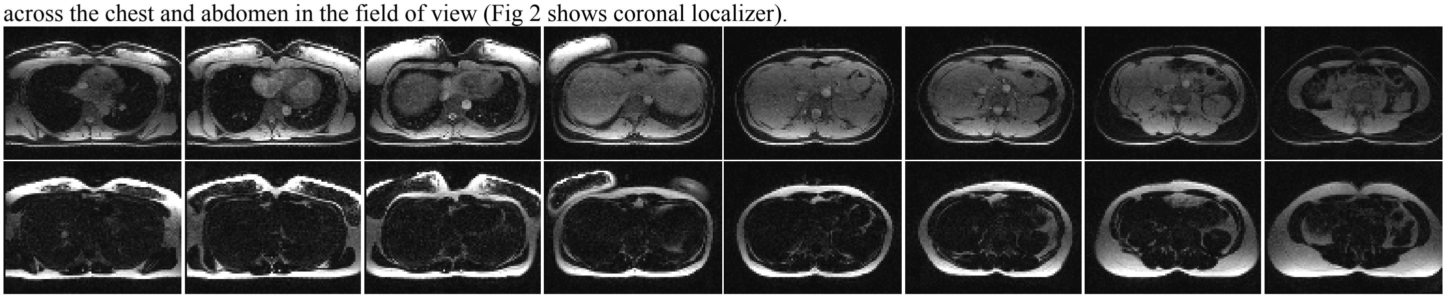

Figure 1. Water (top) and fat (bottom) images for rapid, multi-slice protocol displaying every 6-th slice of 48 acquired in 21s.

Discussion

A rapid multi-slice fat/water separated imaging protocol has been developed for mapping body fat over a large field-of-view. Automated assessment of whole body fat acquired using a continuous moving table 3D acquisition approach has been recently described [4]. The proposed alternative 2D multi-slice protocol is suitable for multi-station implementation and automated coil switching for routine, full body fat determination.

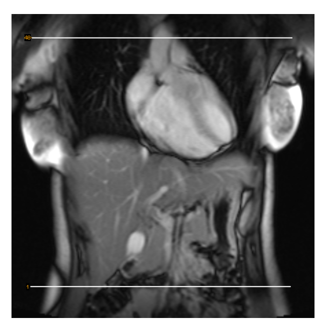

Fig. 2. Localizer for images in Fig 1.

References

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