Improvement of IDEAL Fat-water Separation at Large FOV in the Presence of Gradient Non-linearity and Severe Field Inhomogeneities

J-K. Hsiao[1,2], H-C. Chang[3], and H-M. Liu[1]

[1]Department of Medical Imaging, National Taiwan University, Taipei, Taiwan, [2]Institute of Biomedical Engineering, National Taiwan University, Taipei, Taiwan, [3]MR application specialist, GE Healthcare Taiwan, Taipei, Taiwan

Introduction

The Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation (IDEAL) uses the acquisition of images at three different TEs to separate water and fat components [1]. It produces robust fat and water separation by iteratively finding the optimal field map, which is compatible with multi-coil acquisition. The IDEAL method is, however, problematic in the presence of incorrect convergence of field map solutions [2]. A 2-D linear field map estimation with region growing improves the IDEAL algorithm's immunity to field inhomogeneity [2]. In this work, we propose another option using phase changing during different TEs to semi-automatically estimate field map in regions with severe field inhomogeneities. The proposed scheme is compatible with gradient nonlinear correction near the edge regions of the FOV, hence could improve the performance of IDEAL in larger FOV applications such as the abdomen.

Theory

A simple method to acquired field map is to collect images at two different echo times [3]. IDEAL method already acquires images at three different echo times, and the images at different echo times offer information of field map. There are two main concerns with this approach. One is that the phase map of each image needs to be phase unwrapped [4] if the phase difference exceeds +/-180^{o}. The other concern is the presence of multiple chemical species such as lipids and water. We assume that the phase changes at edge regions of large FOV are dominated by severe field inhomogeneities rather than multiple chemical species with different resonant frequencies. The phase changes between the longest and shortest TEs could then be used to provide a initial coarse estimate of the field map in severely inhomogeneous regions, which could subsequently be applied to the IDEAL fat-water separation algorithm. The flow chart is shown in Fig.1. First, we separate the real and imaginary images with gradient wrapping correction of each RF coil element, and then compute the complex images for each coil. This step ensures that the accuracy of phase value is not affected by the gradient wrapping correction. After the gradient wrapping correction, we manually select the ROIs from four corners of FOV (one shown in Fig.2b). Then the program automatically selects the RF coil element with maximum signal in each ROI to start the field map estimation.

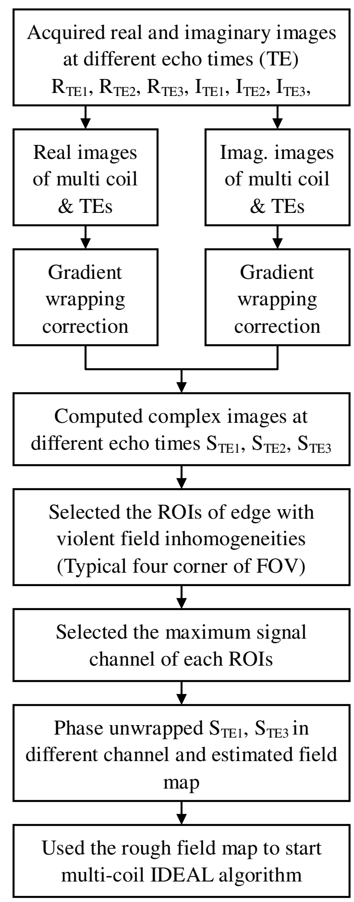

Figure 1. Flow chart of estimating initial field map in regions with severe field inhomogeneities.

Material and method

We collected coronal human abdomen images with large FOV on a 1.5T MRI scanner (Signa EXCITE 2, GE) using an 8-channel phase array body coil. The scan time of a breath-hold gradient echo with positive polar readout acquisition (TE=1.768/4.368/6.968ms, TR=120ms, flip angle=30, NEX=1, Matrix=256x256, slice thickness 10mm, FOV=480x480mm) was about 20 sec. Data post-processing and analysis programs, including phase unwrapping in field map calculation, were implemented under the Matlab 7.0 platform.

Results

The results of fat and water images of IDEAL separation method are shown in Fig.2. The fat and water images separated without our field map estimation showed failed separation at FOV edges (Fig.2a (arrow) & Fig.2b) under large FOV. The estimated field map (Fig.3) showed severe changes of field inhomogeneities that are difficult to estimate through 2D linear fitting, which could be improved substantially using our method (Fig.2c (arrow) & Fig.2d).

Discussion

The results from our study show that IDEAL fat-water separation of large FOV indeed benefits from the estimated severe field map. Phase unwrapping and field map calculation in small ROI is computationally economic and faster than calculation in large FOV, as it only calculates four ROIs before multi-coil IDEAL separation. The improved fat and water separation in edge regions are suitable for clinical applications such as evaluation of liver fat content or estimation of subcutaneous fat volume, which is beneficial in metabolic syndrome patients.

Conclusion

Our field map estimation improves IDEAL fat-water separation in the presence of severe field inhomogeneities with large FOV and is compatible with gradient wrapping correction. Our scheme uses an estimation of four edge regions with severe field inhomogeneities, hence has less computing time and better clinical interpretation.

Reference

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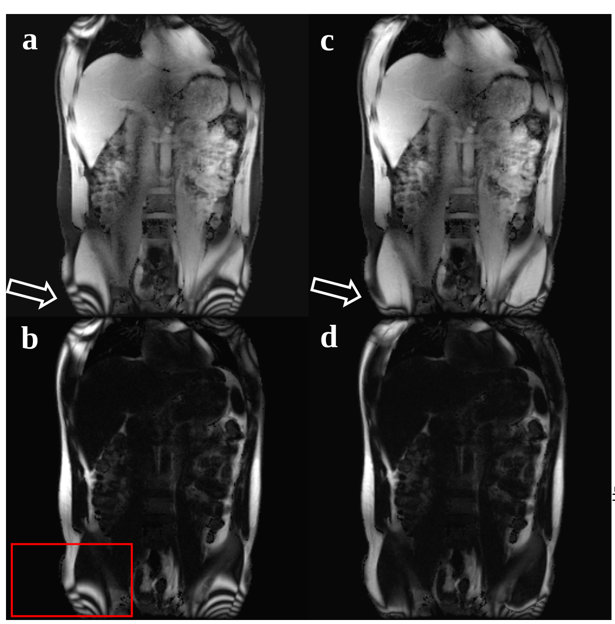

Figure 2. Human abdomen fat & water images using IDEAL fat-water separation without edge field map estimation (a,b), and with edge violent field map estimation (c,d). The ROI in b (red rectangle) is the manually selected ROI for field map estimation.

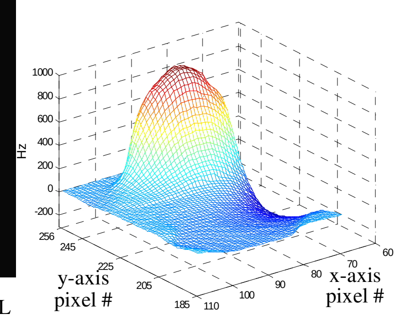

Figure 3. The estimated field map in ROI of Fig.2b shows violent changes of field inhomogeneities.