Accelerated Liver Fat Quantitation Using Parallel Imaging and Compressed Sensing

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INTRODUCTION: Chemical shift-encoded water-fat imaging has recently shown considerable promise as a safe and noninvasive alternative to tissue biopsy for in-vivo liver fat quantitation [1]. However, this technique requires measurements at multiple echo-times; this limits the spatial resolution and/or volume coverage that can be achieved in one breath-held scan. To address this limitation, parallel imaging [2,3] has been used to reduce the scan time [1]. Recently, compressed sensing has been introduced into MRI as a complementary method to parallel imaging for scan time reduction [4]. In this work, we present a combined parallel imaging and compressed sensing framework for liver fat quantitation. The proposed approach is compared to an existing parallel imaging and water-fat quantitation method. We demonstrate more accurate liver fat quantitation at 2.5x 1D acceleration using the proposed approach than with the existing method.

METHODS: <u>Data Collection</u> - Fully-sampled liver datasets were collected from five subjects on a GE Signa EXCITE HDx 3T system (GE Healthcare, Waukesha, WI) using an investigational IDEAL 3D SPGR six-echo sequence and eight-channel torso coil. The acquisition matrix size was 160x160 with 8 axial slices, BW = ±125 kHz, and a flip angle of 5° to minimize T1-bias. The first echo-time was 1.08ms and the echo spacing varied by subject between 0.668 - 0.774ms. The six echoes were collected in three shots (ETL = 2) using unipolar readouts with fly back gradients in an 18-20s breath-hold. <u>Image Reconstruction</u> - The fully-sampled data were undersampled using a jittered grid pattern [6], while also keeping the 16 central phase-encodes, yielding a net acceleration of 2.5x. The undersampled data were reconstructed using a modification of the method proposed by Sharma et al. [7] to now include incorporation of coil sensitivity information (Fig. 1). For reference, the fully-sampled datasets were reconstructed using the T2*-IDEAL method proposed by Yu et al. [5]. For comparison, the fully-sampled data were uniformly undersampled by a factor of 3 while also keeping the 16 central phase-encodes, yielding a net acceleration of 2.5x. The undersampled data were first reconstructed using ARC [3]; subsequently, the synthesized fully-sampled data were passed to the T2*-IDEAL reconstruction. This method will be called ARC/T2*-IDEAL.

RESULTS: Fig. 2 shows the fat fraction (=fat/fat+water) (FF) and R2* image estimates for one of the five subjects using the three reconstruction methods. The average FF and R2* estimates in a region of the liver are also shown. Figs. 3 and 4 show the estimated vs. reference FF and R2*, respectively, for all five subjects. The proposed approach more accurately estimates both FF and R2* than does ARC/T2*-IDEAL.

CONCLUSION: We have presented a combined PI-CS approach for estimating FF and R2* in the liver that outperforms ARC/T2*-IDEAL at 2.5x 1D acceleration based on results in five subjects. Ongoing work is focused on compensating for other possible confounding factors, such as eddy current, as well as further testing.

REFERENCES: [1] Hines et al. JMRI 2011;33:873-81 [2] Griswold et al. MRM 2002;47:1202-10 [3] Beatty et al. ISMRM 2007 p. 1749 [4] Lustig et al. MRM 2007;58:1182-95 [5] Yu et al. JMRI 2007;26:1153-61 [6] Cook. ACM Trans Graph 1986;5:51-72 [7] Sharma et al. ISMRM 2011 p. 2704 [8] Reeder et al. JMRI 2011;34:729-49.
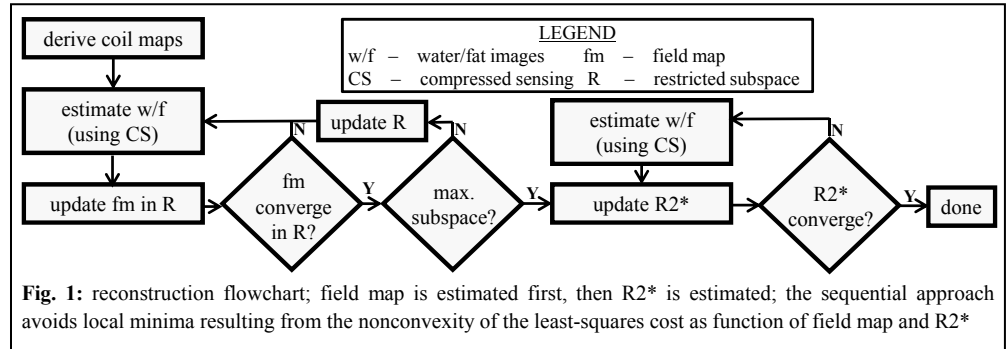
Fig. 1: reconstruction flowchart; field map is estimated first, then R2* is estimated; the sequential approach avoids local minima resulting from the nonconvexity of the least-squares cost as function of field map and R2*
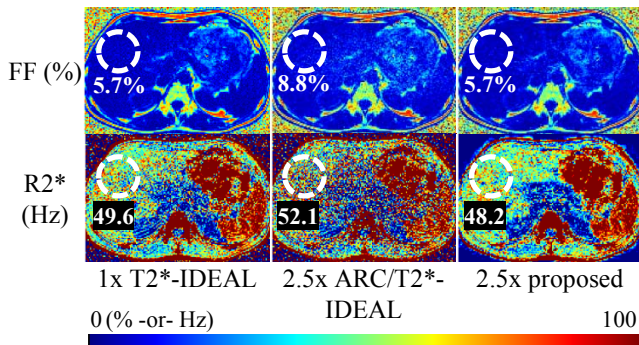

Fig. 2: fat fraction (FF) and R2* estimates for one of the five subjects; the dashed white circle outlines the region in which the average FF and R2* values were calculated; the FF and R2* images are shown using the same 0-100 scale in their respective units; the proposed method accurately estimates the FF while ARC/T2*-IDEAL overestimates FF; an accurate FF estimate is especially important at this level since a 5.56% threshold is commonly used to discern normal from abnormal liver fat [8]
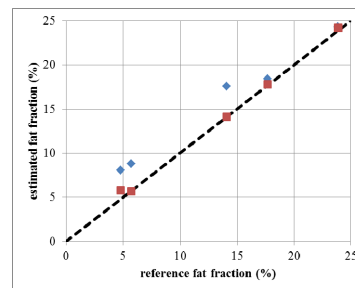

Fig. 3: estimated vs. reference (1x T2*-IDEAL) fat fraction (FF) for ARC/T2*-IDEAL (♦) and the proposed method (■), both at 2.5x acceleration; unity line denoted by dashes; the FF is accurately estimated by proposed method while ARC/T2*-IDEAL overestimates FF when reference FF is low; this bias may be caused by low SNR of the fat signal
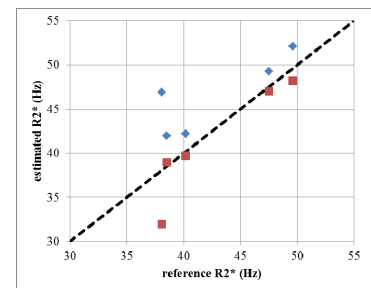

Fig. 4: estimated vs. reference (1x T2*-IDEAL) R2* for ARC/T2*-IDEAL (♦) and the proposed method (■), both at 2.5x acceleration; unity line denoted by dashes; R2* is accurately estimated by the proposed method in four of five subjects whereas the ARC/T2*-IDEAL overestimates R2* in all subjects