**INTRODUCTION**

Fat is a metabolically active component of the human body. Excessive fat in the liver can progress into fibrosis and liver cancer. Chemical-shift encoded magnetic resonance imaging (MRI) [1, 2, 3] has been proven capable of non-invasively quantifying fat fraction in the liver. To work well, these methods require lengthy breath holding and high signal-to-noise (SNR) images. This study aims to develop a free-breathing liver fat and \( R^*_2 \) quantification technique using multi-echo radial FLASH and model-based reconstruction (MERLOT).

**METHODS**

Multi-Echo Radial FLASH Sampling

Figure 1 illustrates the implemented multi-echo radial FLASH MRI sequence [4]. After a radio frequency (RF) excitation with the slice-selection gradient \( G_s \), seven echoes with different \( k \)-space spokes are acquired. The acquired echoes are color coded, while the black solid lines indicate either the ramp or the blip gradients.

Model-based Reconstruction

The acquired MR signal, \( y_{j,m}(t) \), is based on the Fourier transformation:

\[
y_{j,m}(t) = \int d\vec{r} e^{-i2\pi f(t)} r_j \rho_m(\vec{r}) .
\]

(1)

The sampling trajectory \( \vec{k}(t) \) is from the time integral of readout gradients \( G_s \) and \( G_r \) (see Figure 1). When one image voxel contains both water (W) and fat (F) species, the echo image \( \rho_m \) is modeled as:

\[
S : (W, F, R^*_2, f_{Bo}) \rightarrow \rho_m : (W + F \cdot z_m) \cdot e^{-R^*_2 T_{E_{m}}} \cdot e^{i2\pi f_{Bo} T_{E_{m}}}. \quad (2)
\]

Here, \( z_m = \sum_{p=1}^{6} \alpha_p \cdot e^{i2\pi f_{p} T_{E_{m}}} \) denotes the six-peak fat spectrum. \( R^*_2 \) and \( f_{Bo} \) is the transversal relaxation rate and magnetic field inhomogeneity, respectively. Equations (1) and (2) can be chained together and written in the operator form:

\[
y_{j,m} = F_{j,m}(x) := P_m \mathcal{F} M S \mathcal{B}, \quad (3)
\]

with \( x = (W, R^*_2, f_{Bo}, c_1, \cdots, c_N)^T \). \( F_{j,m}(x) \) denotes the forward operator, \( j \) is the the coil index \( [j \in [1, N]] \), and \( m \) the echo index \( [m \in [1, E]] \). The nonlinear operator \( \mathcal{B} \) calculates echo images. Every echo image is then point-wise multiplied by a set of coil sensitivity maps in \( x \), as denoted by \( S \). All coil images are then masked to a given field of view \( M \), Fourier-transformed (\( \mathcal{F} \)), and sampled \( (P) \) at each echo.

Fat and \( R^*_2 \) mapping is achieved via joint estimation of the unknown \( x \), i.e. minimizing the least square difference between the measured data \( y \) and the forward model under regularizations based on a priori knowledge of unknowns,

\[
\text{minimize} \; ||y - F(x)||_2^2 + \lambda_1 ||W(E_1 x)||_1 + \lambda_2 ||T_W(E_2 x)||_1 + \lambda_3 ||x||_2^2 \quad \text{subject to} \; R^*_2 \geq 0 \quad (4)
\]

We applied Wavelet regularisation and temporal total variation (TV) regularisation on the physical parameters in Equation (2), \( \ell^2 \) regularisation on \( x \), and non-negativity constraint on \( R^*_2 \).

**RESULTS & DISCUSSION**

Figure 2 shows reconstruction results of two subjects from the proposed MERLOT, and the Siemens reference method, respectively. Clearly, Subject #7 shows elevated FF values in the liver from both methods, indicating fatty liver disease. \( R^*_2 \) is a physical quantity linearly proportional to iron concentration. \( R^*_2 \) values of both subjects are in the normal range.

**CONCLUSION**

A free-breathing liver fat and \( R^*_2 \) mapping technique has been developed and evaluated in subjects with fatty liver disease.

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**REFERENCES**