An artifacts reducing approach for fat-water separation in spatiotemporally encoded single-shot MRI

Lin Chen[1], Congbo Cai[1], Shuhui Cai[1], Jing Li[1], Miao Zhang[1], Ting Zhang[1], and Zhong Chen[1]

[1]*Department of Electronic Science, Xiamen University, Xiamen, Fujian, China*

Target audience

The target audience is basic scientists and clinical scientists who are interested in fat-water separation.

Purpose

Separation of fat and water signals in MRI is very important for many clinical applications. Multi-point fat-water separation methods, such as Dixon and IDEAL, usually lead to a relatively long scan time. Spatiotemporally encoded (SPEN) single-shot MRI is a recently proposed ultra-fast imaging technique, which possesses great potential to separate fat and water signals in subsecond.[1] The advantage of SPEN method is that it can obtain spatial spin distribution and chemical shift information simultaneously without additional acquisition. Super-resolved (SR) reconstruction is indispensable for SPEN approach because of its low inherent spatial resolution. Some SR reconstruction algorithms have been proposed.[2] These algorithms work fine in general but may result in artifacts due to the vast undersampling and incomplete separation of the water and fat information. The emergence of compressed sensing (CS) theory excites great interest in medical images.[3] The theory provides a foundation to reconstruct better images. In this abstract, we apply CS to the reconstruction of SPEN images to reduce the artifacts and improve the image quality.

Methods

Assume that spatiotemporal encoding is applied along the *y*-axis with a field of view (FOV) L_y and the chemical shift offset is ω_{cs}. The acquired signal can be expressed as

$$S(t) = \int_{-L_y/2}^{L_y/2} \rho_0 \exp\left[\mathrm{i}\left(-\frac{\gamma G_e T_e}{2L_y} y^2 + \frac{\gamma G_e T_e}{2} y - \frac{T_e \omega_{cs}}{L_y} y + \gamma G_a y t + \omega_{cs} t + \text{const.}\right) \right] dy \qquad (1)$$

A discrete form of the data acquisition model is

$$\mathbf{S} = \mathbf{\Phi\rho} \qquad (2)$$

where $\mathbf{\Phi}$ denotes the quadratic phase modulation. According to the CS theory, $\mathbf{\rho}$ can be accurately reconstructed by solving the following minimization problem:

$$\arg\min_{\mathbf{\rho}} \|\mathbf{S} - \mathbf{\Phi\rho}\|_2^2 + \lambda \|\mathbf{\Psi\rho}\|_1 \qquad (3)$$

where λ is regularization parameter governing the tradeoff between the reconstruction error and the sparsity. $\mathbf{\Psi}$ is sparsifying transform. In this abstract, contourlet transform is used to sparsify the image. To evaluate the CS reconstruction algorithm, the conventional method based on filtering and conjugate gradient (CG) was adopted as reference.[2]

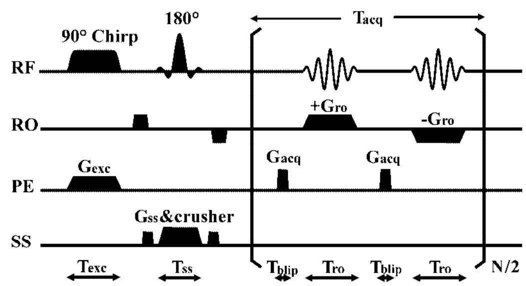

Fig. 1 SPEN single-shot spectral imaging sequence

Results

Experiments were performed on a Varian 7.0 T MRI system using a quadrature-coil probe. The sample was pure water and oil in two separated tubes. The FOV was 45 × 45 mm^2. The excitation bandwidth and duration of the frequency-swept excitation pulse were 64 kHz and 3 ms respectively. The sampling matrix size was 64 × 64, and the sampling rate was 33%. The SR reconstructed matrix size was 256 × 256. The total scan time was 50.5 ms. The vertical axis was frequency encoded and the horizontal axis was phase/spatiotemporally encoded. The 1D spectrum was obtained by Fourier transforming the modified acquired signals.[2] The results are shown in Fig. 2.

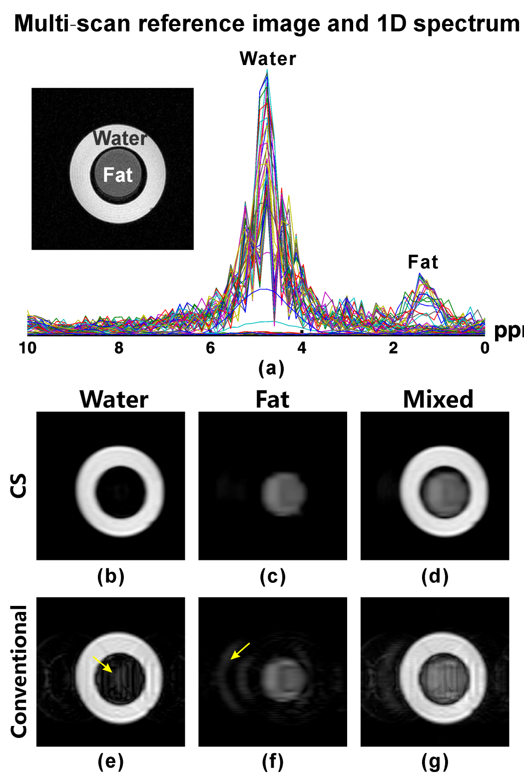

Fig. 2 Separation of water and fat with different reconstruction methods. (a) Multi-scan reference and 1D spectrum. (b~d) Results obtained with CS. (e~g) Results obtained with conventional methods.

Discussion

For conventional method, the information of water and fat are separated by applying an extra filter to the spectrum. Artifacts are generated because of vast undersampling and incomplete separation of two mixed-up chemical shifts. CS employs priori knowledge, that the image can be sparsely represented in some sparsifying transforms, to reduce the artifacts and improve the image quality. From Fig. 2 we can see that the artifacts are obviously eliminated with CS reconstruction.

Conclusion

The efficiency of CS reconstruction in reducing the artifacts and improving the image quality is demonstrated in SPEN experiments. This reconstruction algorithm would benefit the application of SPEN single-shot MRI to fat-water separation.

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