Water-Fat Separation using Time Series Correlation

Markus Florian Untenberger[1], Martin Uecker[2], Dirk Voit[1], and Jens Frahm[1]

[1]Biomedizinische NMR Forschungs GmbH, Max-Planck Insitut fuer biophysikalische Chemie, Goettingen, Niedersachsen, Germany, [2]Dept. of Electrical Engineering and Computer Sciences, University of California, Berkeley, California, United States

Target audience: This abstract is interesting for scientists working with water-fat separation, as well as scientists interested in real-time imaging.

Purpose: We explore a new water-fat imaging method using a real-time data acquisition combined with saturation pulses.

Methods: We acquired undersampled radial FLASH[1] data on a Siemens Tim Trio 3T scanner using different commercial coils. For image acquisition first a saturation pulse (water/fat) is switched, then each image is acquired with typically 31 spokes. The duration of the saturation pulse is T_{Sat}=13ms and the pulse is switched between the frames closest to the pulse repetition time PR =2000ms. This procedure is repeated N times, as displayed in figure 1. With TR/TE = 2.80/1.78ms the acquisition time of each frame is T_{Acq} = 87ms. Other imaging parameters include a flip angle of 8°, a base resolution of 256 or 320, an in-plane resolution of 1mm with 5mm slice thickness and a bandwidth of 1040 Hz/pixel. The data was reconstructed offline using a GPU implemented non-linear inverse reconstruction (NLINV)[2,3] and further processed using Matlab scripts.

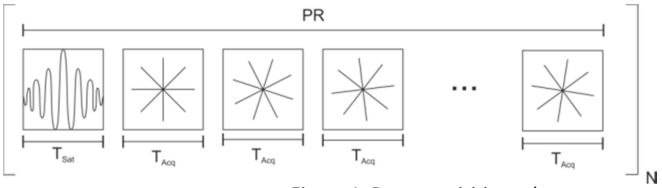

Figure 1: Data acquisition scheme.

A global "paradigm" is obtained from the L2 norm of each image, giving a time series as seen in figure 2. Even if only 2% of all pixels contain the saturated species, a good paradigm is obtained. Then for each pixel time series the Pearson linear correlation coefficient and p-value using a student's t-distribution with the paradigm are calculated. A map is calculated using the absolute value of the logarithm of the p-values < 0.05 with a positive correlation. In this map bright pixels correspond to pixels with high chemical species content, following closely the paradigm. The logarithm reduces the large dynamic range of the p-value to a range with visible contrast and since anti-correlation is an increase in magnetization after the saturation pulse, which is unphysical, these pixels are discarded. A comparison to conventional iterative decomposition of water and fat with echo asymmetry and least squares estimation (IDEAL)[4,5,6,7] is also performed.

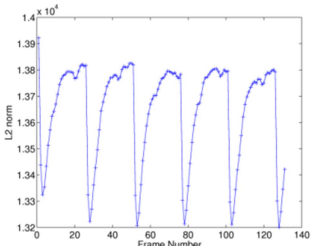

Figure 2: L2 norm for each frame giving the paradigm

Results: For both water and fat saturation we get good agreement with the IDEAL water-fat separation as seen in figure 3. The correlation images contain more noise and the intra tissue specific contrast is reduced.

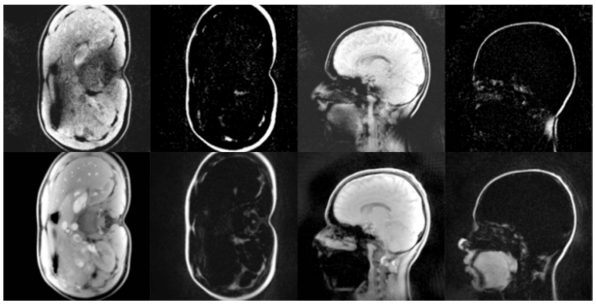

Figure 3: Water and fat images from different parts of the human body. Upper row shows the correlation images and lower row the IDEAL images.

Discussion: This novel method obtains chemical species images using saturation pulses of this species, which contrast conventional use of saturation pulses, where images of the unsaturated species are obtained. But since saturation pulses are used, this method is sensible to off-resonance effects and suffers from B1 inhomogeneity effects, which is seen in figure 3. On the other hand, it does not suffer from phase problems, which are common to other water-fat separation algorithms.

Our method is robust with respect to the used paradigm, we observed no difference between the global L2 paradigm and the from a chemical species pixel modeled paradigm using different parameters. There are however qualitative differences to a simple box-car paradigm.

The proposed method has a longer acquisition time compared to conventional water-fat separation methods, on the other hand the reconstruction time is much less than usual water-fat separation algorithms. Unfortunately it does not account for the spectral complexity of fat and therefore a fat quantification is not possible.

Conclusion: This novel method of creating chemical species images from their saturation pulses is robust and simple, as well as easy to implement and to evaluate.

References:

1. Zhang S, Block KT, Frahm J. Magnetic resonance imaging in real time: advances using radial FLASH. J Magn Reson Imaging. 2010; 31(1):101-109.
2. Uecker M, Hohage T, Block KT, Frahm J. Image reconstruction by regularized nonlienar inversion – joint estimation of coil sensitivies and image content. Magn Reson Med. 2008; 60(3):674-682.
3. Uecker M, Zhang S, Voit D, Karaus A, Merbold KD, Frahm J. Real-time MRI at a resolution of 20ms. NMR Biomed. 2010;23(8):986-994.
4. Reeder SB, Wen Z, Yu H et al. Multicoil Dixon chemical species separation with an iterative least-squares estimation method. Magn Reson Med. 2004; 51(1):35-45.
5. Yu H, Shimakawa A, McKenzie CA, Brodsky E, Brittain JH, Reeder SB. Multiecho water-fat separation an simultaneous R2* estimation with multifrequency fat spectrum modeling. Magn Reson Med. 2008; 60(5):1122-1134.
6. Bydder M, Yokoo T, Yu H, Carl M, Reeder SB, Sirlin CB. Constraining the initial phase in water-fat separation. Magn Reson Med. 2011; 29(2):216-221.
7. Yu H, Reeder SB, Shimakawa A, Brittain JH, Pelc NJ. Field map estimation with a region growing scheme for iterative 3-point water-fat decomposition. Magn Reson Med. 2005; 54(4):1032-1039.