Fat-water separation in a rapid quantitative mapping sequence

Ken-Pin Hwang[1,2], Jong Bum Son[2], Marcel Warntjes[3], Ersin Bayram[1], and Jingfei Ma[2]

[1]*Global MR Applications and Workflow, GE Healthcare, Houston, TX, United States,* [2]*Department of Imaging Physics, The University of Texas M. D. Anderson Cancer Center, Houston, TX, United States,* [3]*Center for Medical Imaging Science and Visualisation, University of Linkoping, Linkoping, Sweden*

Introduction: Several methods exist for mapping T1 and T2 relaxation time and proton density PD simultaneously in a single sequence [1-5] to enable creation of synthetic MR images and robust tissue segmentation. While many of these methods work well in the brain, several challenges must be overcome to create a robust technique in the body. One such problem is the wide variety of tissues resulting in a higher percentage of mixed voxels. Applying fat-water separation would aid in the quantitation of these voxels while also providing an additional dimension of quantitation. In this study, we combine QMAP, a rapid quantitative imaging technique [1-3], with Fast Triple Echo Dixon (FTED), a single pass FSE Dixon technique [6], to acquire additional fat-water information within the same acquisition time.

Methods: The QMAP sequence is saturation delay FSE sequence acquired at multiple saturation delay times and multiple spin echo times, providing a matrix of different tissue contrast images. Spin parameters can then be extracted by fitting a T1 to the different delay times and T2 to the different echo times, and scaling the curves to determine PD. In applying the FTED technique, each readout window is substituted with a bipolar, time symmetric three-echo readout. The receiver bandwidth and sampling window times are adjusted such that the spacings between the three gradient echoes are appropriate for fat-water separation with the three images, maximizing the use of time between the refocusing pulses. Separation is performed on each triplet of images, resulting in a fat image and a water image for each delay and echo time. Since longitudinal relaxation is characterized by a saturation recovery curve with a phase sensitive acquisition, the polarity of the individual water images must be determined by aligning the phase to the image with the highest signal, usually the image with the longest delay time and shortest echo time. Parameter fitting and further processing is then performed separately on water and fat using an SyMRI 7.0 (SyntheticMR, Linköping, Sweden).

A series of brain images and a series of pelvic images were acquired on two separate volunteers. Brain images were acquired using a 12-channel head coil and a 1.5T MR imager (MR450W, GE Healthcare, Waukesha, WI), with the following parameters: FOV = 24.0 cm, matrix = 256x256, slice thickness = 4.0, slice gap = 1.0, number of slices = 30, bandwidth = ±62.5 kHz, TE1 = 20.9, TE2 = 94.2, TR = 4420, ETL = 12, total acquisition time = 5:36. Pelvic images were acquired using a 32-channel torso array coil and a 3.0T MR imager (MR750, GE Healthcare, Waukesha, WI), with same parameters except: FOV = 44.0 cm, thickness = 5.0, matrix = 228x256, TR = 4233, bandwidth = ±166.67 kHz, TE1 = 22.9, TE2 = 91.7, ETL=16, total acquisition time = 4:31.

Four saturation delay times and two spin echo times provided the necessary information for QMAP processing, and splitting each readout into three with the FTED readouts resulted in a total of 24 images per slice. Fat-water separation was performed, resulting in 8 water images and 8 fat images. Parameter fitting resulted in separate T1, T2 and PD maps for water and fat, with the ability to synthesize a range of MR images.

Results: Parameter fitting was successfully performed on the individual water and fat images. Some parameters were more sensitive to some artifacts; proton density could be sensitive to small residual phase differences in fat-water separation. Compared to an unmodified QMAP sequence, acquisition time of this technique was generally shorter compared to the usual clinical protocol, albeit at slight expense to SNR.

Conclusions: We have demonstrated the combination of FTED with QMAP for rapid T1, T2, and PD mapping with fat-water separation in a single sequence. This method may provide the basis of an objective MR screening method for both prostate and breast. Since water and fat are acquired in a single sequence, their values could potentially be compensated for T1 and T2 effects to calculate an absolute scaling of water and fat, and would be inherently co-registered with the other parameters acquired by the same sequence.

References: [1] Warntjes JB et al, Magn Reson Med 2008; 2:320-9. [2] West J et al, Eur Radiol; 2012; 5:998-1007. [3] Vågberg et al. AJNR 2013; 34:498-504. [4] Ma D et al, Nature 2013; 495:187-92. [5] Deoni SC et al, Magn Reson Med 2005; 53:237-41. [6] Ma J et al; Magn Reson Med 2007; 58:103-9.

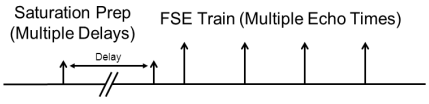

Figure 1. By running a saturation recovery FSE with multiple delay and spin echo times, QMAP acquires contrasts necessary for T1 and T2 relaxation time and proton density mapping.

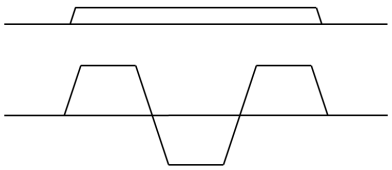

Figure 2. To implement FTED, an FSE readout pulse (top) is split into three echoes centered at the spin echo time. The center echo is in-phase, the outer echoes are out-of-phase.

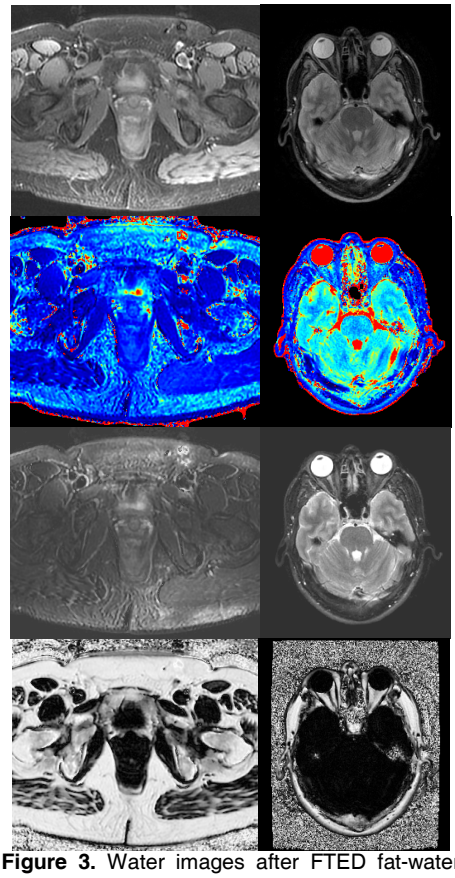

Figure 3. Water images after FTED fat-water separation (top) are processed to produce spin relaxation maps (T2, second row), which can be used to generate synthetic images (T2 weighted, third row). The fat and water information can also be used to calculate fat signal fraction (bottom).