Fat suppression for DW-FSE sequences using an integrated multi-acquisition Dixon method

Tim Schakel[1], Bjorn Stemkens[1], Hans Hoogduin[2], and Marielle Philippens[1]
[1]*Radiotherapy, UMC Utrecht, Utrecht, Netherlands,* [2]*Radiology, UMC Utrecht, Utrecht, Netherlands*

Target audience: Researchers interested in diffusion weighted fast spin echo sequences.

Purpose: In oncology, diffusion weighted (DW) MRI can be used to detect and characterize lesions. In areas with large magnetic susceptibility variations, DW-MRI using the conventional single-shot-spin-echo-EPI can be very challenging and can lead to large image distortion artefacts. When geometric accuracy is vital, e.g. for radiotherapy applications, fast spin echo (FSE) based sequences can provide an alternative [1,2]. For these applications fat suppression is important, since fat can obscure lesions and make images harder to interpret. However, spectral based techniques also suffer from susceptibility variations which can result in incomplete fat suppression. In this work, we integrated a multi-acquisition Dixon method into a DW-SPLICE sequence (figure 1) to facilitate water-fat separation.

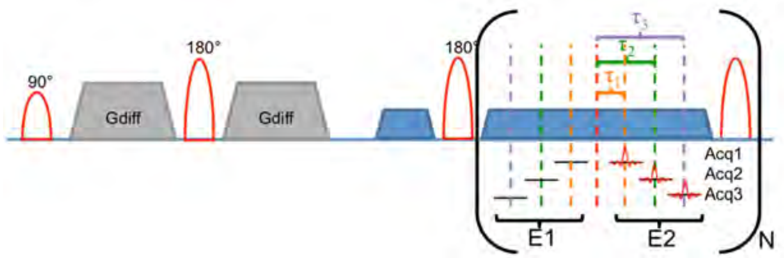

Figure 1: DW-SPLICE sequence diagram. Black bars: data acquisition windows. N = echo train length. For the b=0, the data acquisition windows are shifted by $\Delta\tau$ (=τ_2-τ_1) in subsequent measurements. The DW-SPLICE sequence utilizes a split-echo readout (E1 and E2) to mitigate phase errors due to motion during diffusion weighting [1].

Methods: The sequence was prototyped within the Philips Gyroscan software on a 3.0T Achieva system (Philips, Best, The Netherlands) (figure 1). The b0 (non diffusion weighted image) was acquired 3 times with the acquisition windows shifted by $\Delta\tau$ for each acquisition ($\tau_{1/2/3}$ = 1.12/1.70/2.28 ms). The b>0 measurements were acquired only for the middle acquisition (τ=1.70ms). The data from the different b0 acquisitions were suitable for water-fat separation, which was performed for the E1 and E2 SPLICE acquisitions separately and their results were combined afterwards. From these results water and fat fraction maps [3] were calculated. The b>0 measurements were reconstructed as usual and then multiplied by the water fraction map to suppress the fat. ADC maps were generated using the non fat suppressed DW images. Data processing was performed offline in Matlab (The Mathworks, MA, USA) using ReconFrame (Gyrotools, LLC, Zurich, CH) and the hierarchical IDEAL algorithm [4] from the ISMRM fat-water toolbox.

Image acquisition parameters DW-SPLICE: echo spacing = 9.4 ms, echo train length = 49. TE/TR = 137/10598ms, refoc angle = 50°, halfscan=0.6, SENSE=1.5, FOV: 180x227x120 mm^3 (RLxAPxFH), voxelsize: 1.41x1.41x6 mm^3, b-values=0,300,800 s/mm^2 in 3 directions with a gradient overplus scheme. NSA=4. Total imaging time: 4m56s.

Results: Successful water-fat separation was achieved in the b0 images over the whole field of view; figure 2 shows 2 typical slices (a-e and f-j). By comparing 2c/h with d/i the effect of the fat suppression on the diffusion weighted b800 images can be observed.

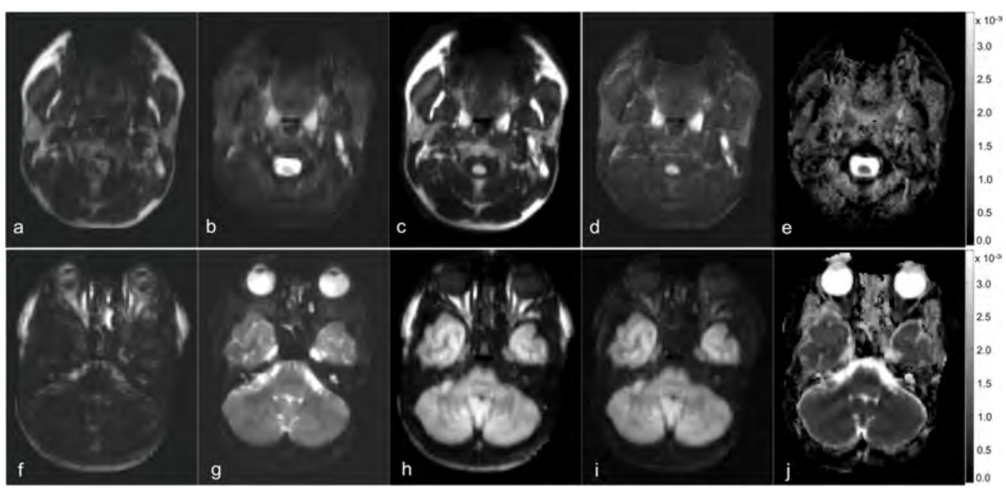

Figure 2: Two slices of DW-SPLICE sequence with integrated Dixon acquisition in the head-and-neck area of a healthy volunteer **(a,f)** b0-fat, **(b,g)** b0-water, **(c,h)** b800, **(d,i)** b800 water weighted, **(e,j)** ADCmap in mm^2/s.

Discussion: Water-fat separation could be performed using the hierarchical IDEAL algorithm. Even though the volunteer had a metal wire behind the teeth (signal void in figure 2 top row), water-fat separation was successful here. Only the b0 image needs to be acquired at different echo times. This could be included in the already present signal averages. In the presented results the echo spacing was increased by 2.4ms ($2(nAcq-1)\Delta\tau$) compared to the normal DW-SPLICE sequence, lengthening the acquisition by 20%. Water-fat separation could not be performed in the b>0 measurements, due to the random phase offset introduced by bulk motion during the diffusion weighting gradients [1], which could not be accounted for in current water-fat separation algorithms. The ADC values in tissues containing a larger percentage of fat might be inaccurate due to the presence of signal from fat during acquisition. Since fat has a lower ADC value than water, this could lead to an underestimation of the ADC value. However, for lesion detection and delineation the undistorted, fat suppressed high b-value images are most important.

Conclusion: A multi-acquisition Dixon method has successfully been integrated in a DW-SPLICE sequence to achieve good fat suppression in an undistorted DW image in difficult areas, such as the head and neck region.

References: [1] Schick, Magn Reson Med 1997 Oct;38(4)638-44, [2] Schakel, In proc ISMRM 2013 #3443 [3] Liu, Magn Reson Med 2007 Aug:58(2):354-64, [4] Tsao & Jiang, Magn Reson Med 2013 Jul;70(1):155-9.