Myelin-Water Imaging at 3T with Linear Combination (LC) Filtering

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Introduction: Abnormal myelin-water concentrations have been reported in multiple sclerosis lesions as well as schizophrenia patients (1,2). Myelin-water has a substantially shorter T2 (10-20 ms) than tissue water (70-90 ms) in white matter (1,3). Recently a linear combination (LC) filtering method was presented (4-5) for short T2 selective myelin-water imaging at 1.5T. By carefully designing the LC filter a six-slice myelin-water image can be generated using only 5 min of scan-time (6). In this work we will design a three-echo LC filter for myelin-water imaging at 3T.

Theory: Traditional short T2 myelin-water imaging methods employ a Carr-Purcell-Meiboom-Gill (CPMG) acquisition sequence to acquire a multi-echo single-slice dataset (1-4). The multi-echo data is then fit to a multi-exponential model using the non-negative least-squares algorithm. By summing over the contributions expected from myelin-water one can estimate the myelin-water fraction (1-3). However the CPMG sequence requires long scan times and only a single slice is acquired (1-4). Recently LC filtering was proposed as an alternative to NNLS fitting (4-5). With LC filtering the multi-echo data set is linearly combined to generate a short T2 image. A different set of weights can be used to generate a uniform image from the same source images. The short T2 image is then divided by the uniform image to obtain a myelin-water fraction image. By carefully choosing the echo times and weights only three echo times are required to generate the myelin-water fraction image at 1.5T (6). As only three echo times are required multi-slice spin-echo sequences can be used.

Methods: We used the following literature values for myelin-water at 3T 10-20 ms, tissue water to have T2’s from 60-70 ms and CSF to have T2’s from 500 ms to 5 s (7,8). One healthy volunteer was scanned using the three-echo LC filter. All MR imaging was performed using a Siemens 3T Trio scanner. Data were collected using two passes of three consecutive six-slice, spin echo acquisitions with the calculated TR/TE parameters for the three-echo filter. Slice thickness was 8 mm, skip 0 mm, 256 mm FOV, 128x128 matrix, aligned to the AC-PC plane. Total scan time was 11 min. The resulting images were then linearly combined to form a myelin fractional image. A region of interest was drawn over the white matter in each hemisphere, and the average MF was calculated.

Results: Only three echoes were required, TR/TE = (698/8, 723/33, 800/100) and weights short T2 selective: 2.5/-4.2/1.8, uniform: 0.7/0.4/-0.1. Myelin images are shown in fig 1. Average MF was 15 +/- 6 for the left hemisphere and 13 +/- 6 for the right hemisphere.

Discussion/Conclusions: The resulting MF is consistent with the literature where 10-15 % MF is reported (1-4, 6-8). We are currently studying any potential SNR benefits of 3T compared to 1.5T

References:
(1) Mackay et al. MRM 31:673;1994
(2) Flynn et al. Mol. Pysch. 8:811;2003
(3) Henkelman et al. MRM 32:592;1994
(4) Jones et al. MRM 51:495;2004
(5) Brosnan et al. MRM 8:394;1988
(6) Vidarsson et al. MRM 53:398;2005
(7) Does et al. MRM 47:274;2002
(8) Stanisz et al. MRM 54:507;2005

Figure 1. Simulated signal vs. T2 for the LC filters used in this work. The short T2 selective filter is designed to image only myelin-water. Dividing the short T2 image by the uniform image then generates the myelin-water fractional image. Both filters use the same three echoes.

Figure 2. Myelin images from a healthy volunteer at 3T. (a) Anatomic T1 weighted image (TR/TE = 698/8 ms). (b) Myelin fractional image. As expected we see myelin-water fractions around 10-15 % (1-4,6-8).