Myelin imaging with matched spin-echo pulse pairs

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Introduction: Myelin is known to have a relatively short T_2 relaxation time(1,2). This has been successfully exploited to generate a myelin only image in both healthy volunteers and MS patients(1-3). Traditionally a multiple-echo dataset has been acquired, and then a non-negative least squares (NNLS) fit is performed to extract the short- T_2 myelin component (1,2). On the same dataset, linear combination filters have been shown to yield equivalent results (3), however linear combination filters can be designed with only three echoes (4), compared to 32 echoes typically used with NNLS processing (1-3). This enables us to acquire a myelin image with three simple spin echoes. The use of conventional spin echo sequences poses a problem as the minimum echo time achievable on our GE Excite 1.5T scanner is only 8 ms. Myelin with a T_2 of about 10 ms (1,2,3), suffers from severe T_2 decay at an 8 ms echo time. Using a custom spin-echo pulse pair substantially shorter echo times can be achieved (5,6), reducing T2 decay. In addition spin-echo pulse pairs are slice selective, thus multi-slice imaging can be performed. In this work we utilize a spin-echo pulse sequence to selectively image myelin at a higher SNR than when using a conventional spin-echo sequence.

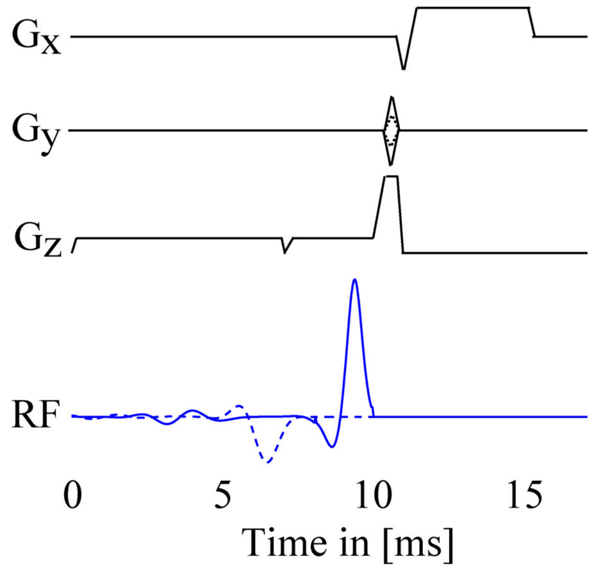

Figure 1: Our spin echo pulse sequence for the shortest echo time of 5.8 ms. As no crusher gradients are used, shorter echo times can be achieved. This results in a degraded slice profile, which can be improved by using phase cycling.

Pulse sequence: The spin-echo pulse pair was designed using the Shinnar-Le Roux (SLR) RF-pulse design method (5,6). As short echo times are desired, there is no room for traditional crusher gradient pulses, thus both the excitation pulse and the refocusing pulse must be carefully designed. Phase cycling effectively eliminates parasitic signals from the refocusing pulse(5). Although scan time is increased two-fold, the data was averaged improving SNR, thus the SNR efficiency is unchanged. To further achieve shorter echo times a 5/8ths partial echo was used for the first echo time along with a homodyne reconstruction. Using this sequence we have achieved echo times as short as 5.8 ms, and as long as 110 ms. As with a traditional spin-echo sequence the slice profile is identical for longer echo times and can easily be used with the linear combination algorithm for myelin imaging (4). The pulse sequence is shown in Fig 1.

Methods: An optimum three-echo linear combination filter was designed with a T_2 pass range from 5 to 20 ms designed to image myelin, a fifty-fold suppression range for T_2's from 75 ms to 85 ms to block tissue water, and a ten-fold suppression region for T_2's from 200 ms to 5 s (4). The filter design algorithm was run again to simulate the effects on SNR if one used a traditional spin echo sequence (min TE of 8 ms, max TE of 110 ms), or an ideal sequence (min TE of 0 ms, max TE of 110 ms). A healthy volunteer was imaged using our spin-echo pulse pair, SNR was measured in the corpus callosum in genu of the healthy volunteer.

Results: The three echo times for our spin-echo sequence were 5.8/26/110 ms, and weights 2.1/-3.1/0.9. The SNR of the corpus callosum in genu, was 15.56. The filtered image is shown in fig. 2. Simulated SNR for the traditional spin echo sequence was 0.78 and 2 for the ideal sequence relative to our spin-echo pulse pair sequence with a simulated SNR of 1.

Discussion: The results show that there is a substantial improvement going towards shorter echo-times. If the echo time could be further shortened the SNR efficiency could be improved by most a factor 2. We are currently working on improving our pulse sequence to further reduce the shortest echo time achievable.

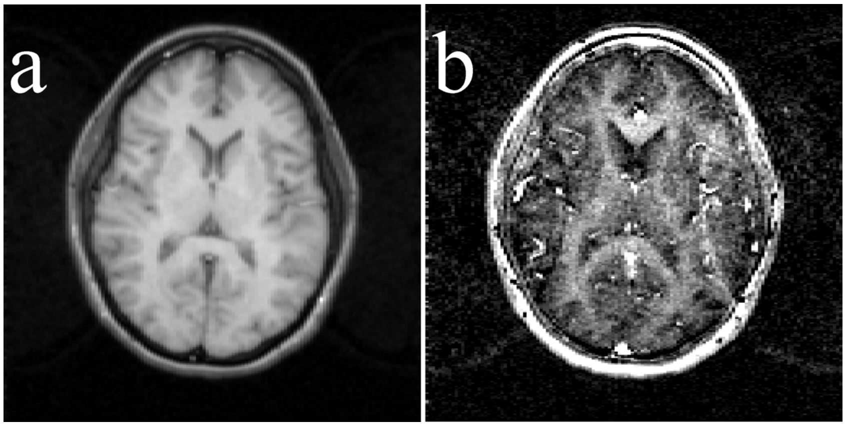

Figure 2: (a) T1 weighted image of a healthy volunteer (TE/TR=25/715 ms), (b) myelin image of the same slice using our spin-echo pulse with linear combination filtering.

References: (1) MacKay et al. MRM 21:673-7(1994)
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(6) Pauly et al. #3902 ISMRM (1992)