A T2-Diffusion-Prepared Cube Sequence for Brain Lesion Detection at 7T

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Introduction: Brain lesion detection at 7T is complicated by the T_1 lengthening observed for white and grey matter without a corresponding increase in CSF T_1. As a consequence, there is lower SNR and contrast for all tissues of interest in FLAIR sequences designed to null CSF signal. The recently developed MP-FLAIR 3D FSE sequence [1] introduced a magnetization preparation sequence to initially saturate white/grey matter M_z so as to allow for greater recovery during the FLAIR inversion period, reducing T_1 weighting and improving SNR. In this preliminary work, we examine the possibility of eliminating the inversion preparation entirely, using instead a combined T_2 and diffusion preparation sequence, with the goal being CSF signal suppression due to it's higher diffusion [2], and simultaneous introduction of combined T_2/diffusion contrast between white/grey matter and lesions [3].

Methods: We have implemented a non-selective T_2/diffusion-preparation module for a Cube acquisition (see Fig. 1). Due to RF inhomogeneity at 7T, we use an adiabatic 90° BIR4 [4] pulse to accurately tip magnetization into the transverse plane where it is then twice-refocused using two adiabatic 180° sech [4] pulses, before a final 270° BIR4 restores magnetization to the z-axis. Bipolar gradient lobes surrounding the 180° pulses provide diffusion weighting and had their relative widths adjusted to mitigate eddy current artifacts [6]. In order to limit SNR loss, we apply the bipolar lobes simultaneously on all axes in order to minimize T_{MP}, the T_2/diffusion preparation period. This will provide anisotropic diffusion weighting ([1,1,1] direction). T_{MP} varied between 55ms to 65ms depending on the desired b-value. Each gradient lobe had a maximum amplitude of 50 mT/m and a combined slew rate over all 3 axes of 50 T/m/s. Scanning was performed on a healthy male volunteer on a GE 7T scanner with a 32-channel head coil. TE/ETL/TR was 14.3ms/60 echoes/and 10 RR intervals or ~8s. Frequency/phase FOV was 20cm/20cm with 192/128 encodes. 2x2 ARC reconstruction was used. Sampling was done using center-out pseudo-radial k-space ordering in k_y-k_z. In order to reduce pulsatile flow and motion artifacts, plethysmograph gating was used with a cardiac trigger to sequence delay of 300ms. The total scan time was 6.5 min.

Results: Figure 2 presents simulations of the prepared Mz based on published diffusion and T2 values [3], and shows that positive lesion contrast to white and grey matter signal would occur above b = 700, T_{MP} = 62ms. Figure 3 shows *in vivo* images with increasing b-values. As the b-value increases CSF suppression is more effective. The level of CSF suppression shows some spatial dependence with more effective suppression seen in the left hemisphere. Despite the cardiac gating, motion artifacts are manifested through ghosting and blurring and are more dramatic at higher b-values. We also observe a dark central region. This signal drop could arise from B_1 inhomogeneities affecting the RF excitation of the Cube sequence.

Discussion: A novel T_2/diffusion preparation sequence for 3D imaging was implemented at 7T. This technique is an alternative to inversion recovery for CSF signal suppression, and so could be a method to shorten the TR compared to the MP-FLAIR sequence. Simulations demonstrate that positive contrast could be produced for brain lesions compared to CSF, white and grey matter, but this needs to be verified *in vivo*. Future work will reduce motion sensitivity by including phase navigators and iterative reconstruction [7]. Optimized isotropic diffusion weighting gradients [8] will also be incorporated to provide more uniform contrast and CSF suppression.

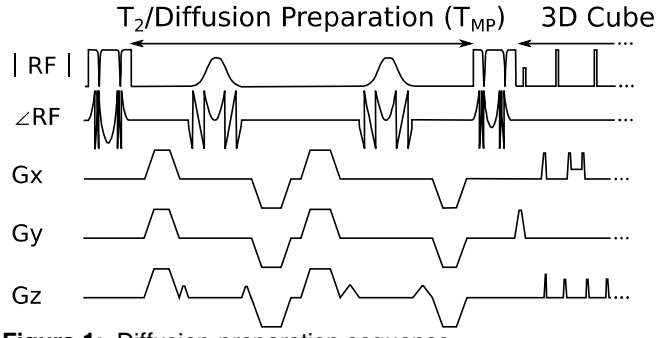

Figure 1: Diffusion-preparation sequence

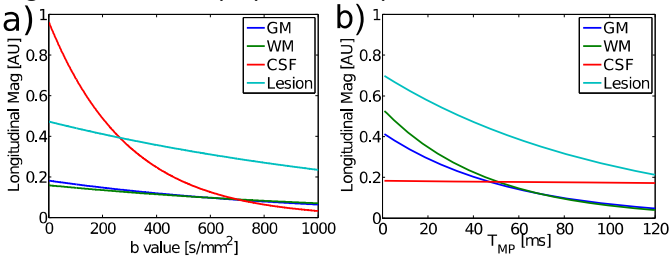

Figure 2: Simulation of prepared M_z a) Dependence on diffusion weighting b (T_{MP} = 65ms) b) Effect of T_2 decay during T_{MP} (b = 500 s/mm^2)

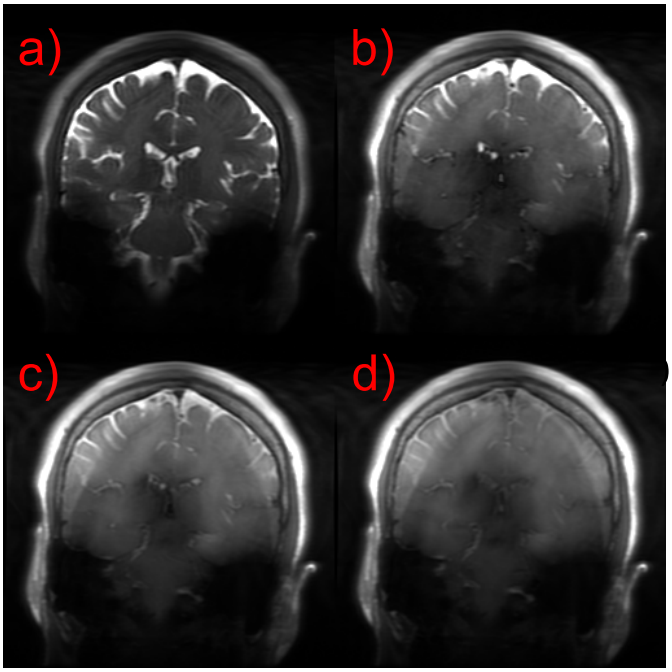

Figure 3: Coronal slice from diffusion-prepared 3D FSE sequence with diffusion weighting a) b= 0 s/mm^2 b) b = 300 s/mm^2 c) b = 600 s/mm^2 and d) b = 1000 s/mm^2

References: [1] de Graaf *et al.*, Eur Radiology 22(1):221-231 2012. [2] Gao *et al.*, JMRI, 33(5):1177-1183 2011. [3] Rosso *et al.*, AJNR, 33(9):1006-1008 2006. [4] Garwood *et al.*, JMRI 153: 155-177 (2001) [6] Reese *et al.*, MRM, 49(1): 177-82 [7] O'Halloran *et al.*, MRM, 68(2): 430-440 [8] Wong *et al.*, MRM, 34(2): 139-143 1995

[This work partly supported by NIH P41 RR09784, NSF GRFP, and GE Healthcare]