Reduced Scan Time 3D FLAIR using Variable Repetition Time

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Introduction: FLAIR imaging has undergone rapid progress so that 3D imaging of the entire brain using an extended modulated refocusing pulse train is possible within a clinically reasonable time [1]. However, a longer repetition time (TR) is still used to allow adequate signal recovery. Here we describe a technique which uses variable repetition time to reduce total scan time. In this manner, scan time is reduced considerably while maintaining excellent CSF suppression. SNR and CNR compare favorably to the full repetition time sequence.

Materials and Methods: *Rationale:* The effective inversion time or the effective echo time (TE_{eff}) of a sequence is defined as the time from excitation to $k_y = 0$. In a similar fashion, the effective repetition time TR_{eff} of a 3D acquisition corresponds to the TR of the $k_z = 0$ encoding line. By reducing the TR for $|k_z| > 0$ encoding lines, we expect that the contrast for the variable TR sequence will exhibit similar signal and contrast as that for the full TR sequence in which TR is constant and identical to that of the $k_z = 0$ encoding line.

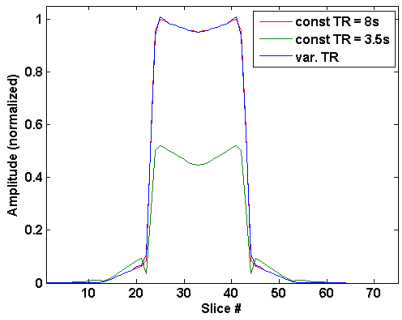

Figure1: T1 (CSF) filtering effect on slab profile induced by different TR schemes.

Sequence design: The 3D FLAIR sequence was modified by varying the TR in a predetermined smooth fashion from TR_{min} to TR_{max} (both user defined) over the k_z encoding space such that TR_{min} corresponded to the highest k_z line and TR_{max} to the k_z=0 line using a four term Blackman-Harris (B-H) window. Thus $TR_{eff} = TR_{max}$. The B-H window shows a favorable response in the transformed (image) domain. Each inversion is followed by the turbo spin-echo train at a constant TI and TE, followed by dead time (constant or varying) during which M_z recovers. Figure 1 shows the effect on slab profile (worst case scenario corresponding to CSF T1) of varying the TR from 3.5s to 8s using the B-H window compared with a long constant TR of 8s and a short constant TR of 3.5s.

MRI experiments: Two phantoms with 2 different T1s (phantom 1 T1=2410 ms and phantom 2 T1=884 ms, measured using IR-SE sequence) and 5 healthy volunteers were imaged under an IRB approved protocol on a 3T Philips Achieva (software release 3.2.1) scanner. The reference 3D FLAIR "full TR" sequence used TR 8000 and was compared to the "variable TR" sequence in which TR was modulated from TR_{min} 3500 to $TR_{eff=max}$ 8000. Additional scan parameters were identical between the two sequences in each patient: sagittal acquisition, FOV=24-25cm, TI = 2400 ms, TSE acquisition $TE_{eff} \approx$ 275ms, etl = 182, min refocusing = 18°, resolution ≈ 1×1×1mm, # of slices=300-321, SENSE (k_y, k_z) = (2.6, 2); NSA=2. Scan duration was ≈ 6m20s for the "variable TR" FLAIR and ≈ 8m for the "full TR" FLAIR . Since parallel imaging was employed, SNR was measured using ROIs placed in corresponding magnitude and noise only images. SNR was measured in the grey matter (GM), white matter (WM) and CSF.

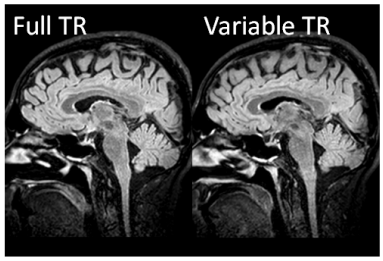

Figure 2: CSF in the lateral and third ventricles, cerebral sulci, and cisterna magna is well suppressed.

Results: In phantoms, comparison of SNR for full TR and variable TR 3D FLAIR gave only minor differences (0.3% in phantom 1 and 3.3% in phantom 2). CSF suppression for the "variable TR" sequence was excellent and comparable to that of the "full TR" (Figure 2) sequence. SNR for WM, GM and CSF for the 5 volunteers was comparable (Figure 3). Unexpectedly, GM-WM CNR was higher for the variable TR sequence when compared with the full TR sequence (9.5 vs 5.9). CSF suppression was also better (SNR 6.3 vs 10.6). On visual inspection, conspicuity of white matter hyperintensities (seen in 3 volunteers) was similar between the two methods (Figure 4). Axial reformat of the sagittal images revealed some blurring next to CSF in the slice direction (Figure 5).

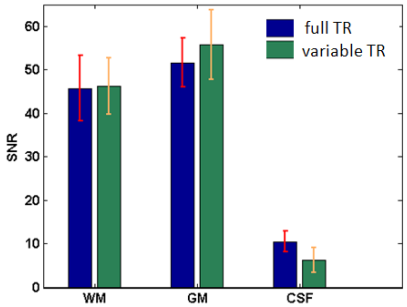

Figure 3: SNR measurements

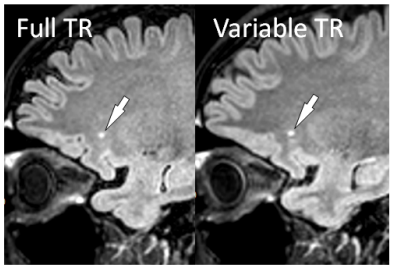

Figure 4: White matter hyperintensity (*arrow*)

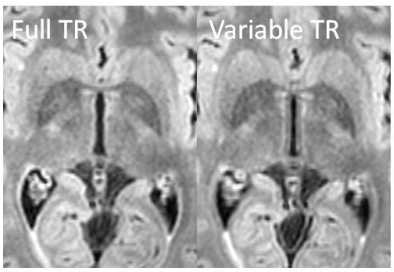

Figure 5: Blurring of the third ventricle

Discussion: A new technique for reducing scan time by varying TR was described. 3D FLAIR with varying TR compared favorably to the traditional 3D FLAIR using a constant full TR. Note that the scheme works only with 3D acquisition as it varies TR along k_z. Savings in scan time is proportional to the TR used, i.e. greater time reduction occurs with larger TR_{max}. Both SNR and CNR of GM and WM was greater with the varying TR sequence. Since actual data acquisition time is the same in both cases, this could be due to the effective TI being slightly different for the varying TR sequence. SAR values increased for the varying TR sequence but were well below FDA approved limits. Current optimized 3D FLAIR sequences do not necessarily acquire k_z space in a linear fashion. This is handled by using the appropriate TR for the corresponding k_z encoding.

References: [1] B.A. Landman et al. Neuroimage, 2011:54:2854 -2866.