FLUID-ATTENUATED THREE-DIMENSIONAL STRUCTURAL BRAIN MRI USING INVERSION-RECOVERY-PREPARED DANTE-FLASH (IR-DASH)

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Background: In functional neuroimaging the T1-weighted 3D MP-RAGE sequence is often adopted as the standard sequence for brain structure image acquisition because of its high imaging efficiency, good cerebrospinal fluid (CSF) signal nulling properties and its excellent grey matter (GM) / white matter (WM) contrast. However, due to the blood inflow effects of MP-RAGE, the signal from cerebral blood tends to be hyper-intense, especially near the grey matter of the frontal lobes and insula cortex. This signal contamination from blood may cause difficulties with image segmentation of GM. DANTE (Delays Alternating with Nutation for Tailored Excitation) pulse trains are a rapid series of low flip angle non-selective RF pulses interspersed with gradients. It has been previously demonstrated that when DANTE pulse trains are used as a preparation module prior to imaging readout, the longitudinal magnetization of flowing spins is substantially attenuated, whereas the longitudinal magnetization of static tissue/fluid is mostly preserved [1] with relaxation weighting of sqrt(T_1/T_2). Considering the very similar T_1:T_2 ratio of GM and WM, we may reasonably assume that DANTE may be capable of suppressing the blood signal without changing the original WM/GM contrast from MP-RAGE. Meanwhile, any signal loss due to the relaxation weighting of the DANTE preparation may be compensated for by the use of a centric phase encoding scheme [2]. In this study we introduce an inversion-recovery-prepared 3D DANTE-FLASH sequence (denoted as 'IR-DASH') that is able to generate 1 mm isotropic resolution full brain images with attenuated fluid (arterial blood and CSF) signal and comparable $CNR_{(WM/GM)}$ to conventional MP-RAGE images. We also test whether the segmentation of GM can be improved due to the blood suppression benefits of the DANTE pulse trains.

Materials and Methods: Subjects: 4 healthy volunteers (males, 24 to 35 years) underwent 3D MP-RAGE and 3D-IR-DASH imaging. Written informed consent was obtained from all subjects. All scans were acquired using a 3T Siemens Verio scanner and 32-channel Rx head coil. *Protocol*: axial imaging acquisition, 3D-MP-RAGE: FOV=192×172×192 mm, matrix size 192×172×192, 1 average, FLASH flip angle α = 10°, slice resolution = 75%, Fat suppression = water excitation-normal phase, $TR_{internal}$ = 10 ms, BW = 130 Hz/pixel, linear phase encoding along *z* in each TR, TR=2s. 3D IR-DASH: FOV=192×172×160 mm, matrix size 192×172×160, 1 average, FLASH flip angle α = 14°, slice resolution = 75%, Fat suppression = water excitation-normal, $TR_{internal}$ = 10 ms, BW = 130 Hz/pixel, , phase partial FT = 6/8, centric phase encoding along *z* in each TR, TR=2760ms, TI=900 ms and TD=450 ms, No RF-spoil. Both protocols yielded 1mm isotropic resolution and a 360 s imaging time. Parameters for the DANTE module: flip angle (FA) α = 12°; Number of DANTE pulses N_p=150; t_D=1 ms; $G_{x,z}$=20 mT/m; gradient duration≈1 ms. *Analysis*: $CNR_{(WM/GM)}$ (WM and GM signal difference divided by noise level) was calculated. Segmentation was carried using a series of FSL software tools including FLIRT (Linear Image Registration Tool), BET (Brain Extraction Tool) and FAST (FMRIB's Automated Segmentation Tool).

Results: Bloch simulation of the IR-DASH sequence (Fig. 1) predicted a 20% signal loss in both WM and GM, indicating that the original contrast from MP-RAGE would be preserved. Measurement of $CNR_{(WM/GM)}$ from the images in Fig. 2 showed an actual improvement of 39 for IR-DASH vs 33 for MP-RAGE. This improvement might be caused by the use of centric phase encoding[2] and the larger readout flip angle applied in the case of IR-DASH.

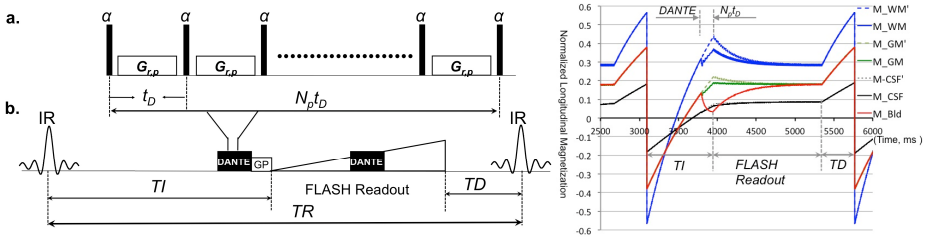

Fig. 1. a) DANTE diagram. b) Single-TR IR-DASH sequence timing diagram. Note, one DANTE pulse train is placed immediately before the readout, with another inserted in the middle of the readout (no readout running at the same time) for further blood suppression with no gradient preparation (GP). Bloch simulations (right panel) show the longitudinal relaxation effects of IR-DASH for the sequence shown in Fig.2b. Dotted lines and solid lines represent the relaxation effects of centric phase encoding without and with DANTE preparation, respectively.

Fig. 2 clearly demonstrates the improvement of image quality in the insula regions due to the blood suppression. Without blood signal contamination, a marked improvement in GM segmentation in the frontal lobes is shown in Fig. 3.

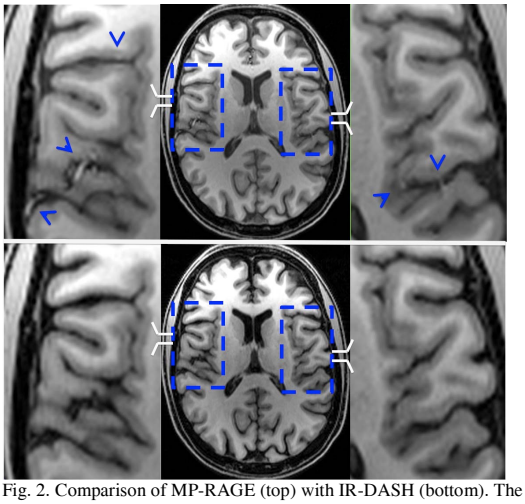

Fig. 2. Comparison of MP-RAGE (top) with IR-DASH (bottom). The left and right insula cortices for both sequences are shown magnified. Hyper-intense blood signal is indicated by blue arrows in the MP-RAGE image. Due to blood suppression of DANTE, the delineation of GM vs CSF in the IR-DASH image is significantly improved.

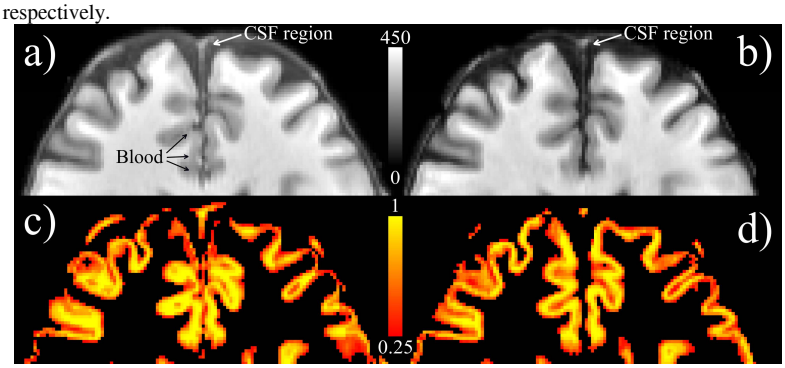

Fig. 3. Comparison of grey matter segmentation between conventional MP-RAGE and IR-DASH images. a) and b) were MP-RAGE and IR-DASH images registered, respectively, to a standard brain structure image. CSF regions and blood signals are marked with arrows. c) shows the result of grey matter segmentation from a). d) shows the result of grey matter segmentation from b). Results b) and d) clearly indicate the improvement of IR-DASH over MP-RAGE.

Conclusion: IR-DASH is a promising new sequence for fluid-attenuated 3D-MR imaging of brain structure, and yields improved GM segmentation vs MP-RAGE.

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References: [1] Li L, Miller KL, Jezzard P. Magn Reson Med. 2012; 68:1423-1438. [2] Deichmann R et al. NeuroImage. 2000; 12:112-127.