Comparison of DANTE Prepared Black Blood (BB) -TSE with Conventional BB Methods

Linqing Li[1], and Peter Jezzard[1]
[1]*FMRIB, Clinical Neurology Department, University of Oxford, Oxford, United Kingdom*

Background: We have previously demonstrated [1] that during application of DANTE (a rapid series of low flip angle RF pulses interspersed with gradients) pulse trains, longitudinal magnetization of flowing spins is largely (or fully) attenuated due to phase dispersion accrued while flowing along the applied gradient. This is in contrast to static tissue, whose longitudinal magnetization is mostly preserved. This progressive saturation of flowing spins is insensitive to velocity (above a threshold). Preliminary comparison of T_1 weighted multislice imaging between DANTE, DIR [2] and iMSDE [3] preparation modules showed that DANTE is a very promising BB technique [1]. In this work, a more comprehensive comparison of T_2 weighted and proton density imaging was performed. In addition, further application to a DANTE-prepared multi-slab 3D GRASE sequence was investigated.

Methods: The proposed DANTE-BB imaging sequence is shown in Fig. 1, indicating both the DANTE preparation module itself, as well as the proposed method for embedding it within an imaging readout method, such as a TSE. N_p is the number of pulses applied in the DANTE module. T_D in Fig. 1b represents the inter-DANTE module delay time reserved for the readout module. Eight healthy volunteers (male, ages 24-35 years) underwent carotid artery wall MR imaging, acquired using a 3T Siemens Verio scanner with a 4-ch Siemens neck coil. For quantitative comparison [3] we define the SNR as SNR=0.695S/σ, where S is signal intensity and σ is standard deviation of the noise. The contrast-to-noise ratio (CNR) is defined as $CNR_{ml} = SNR_{muscle} - SNR_{lumen}$ where 'ml' indicates muscle-lumen. The definition for CNR_{eff} is then given by $CNR_{eff} = CNR_{ml} / (T_{SA})^{1/2}$ where T_{SA} is the average scan time for each slice. All protocol parameters are listed in the tables below.

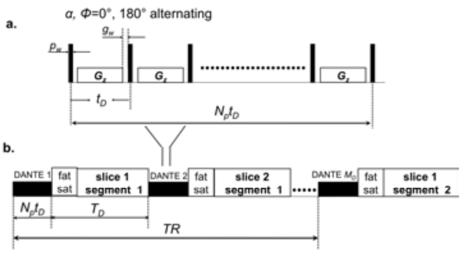

Fig 1. DANTE multislice interleaved acquisition

Table 1. T_1 weighted imaging protocols

	TR (ms)/TE(ms)	receiver bandwidth (Hz/pixel)	Turbo factor	slices/gap	Concatenation groups	Acq time (mins)	BB module
Common parameters for read-out 2D TSE image protocols FOV = 150 × 150 mm, matrix size 256 × 252, 256× 252× 8 for 3D interpolated to 512 × 512, slice thickness = 2mm, Number of average =1, TI=780ms							
DIR	780/13 (ECG triggered)	130	9	5/100% sequential	N/A	2.5	DIR, Siemens product module, 1 pulse triggered
iMSDE	2000/ 9.5 (no ECG)	247	12	6/100 % interleaved	2	1.5	G_z=20mT/m, G duration=4.4ms
DANTE	2000/13 (no ECG)	130	7	22/no gap interleaved	2	2.5	flip angle (FA) α = 7°-9°; Np=64; time duration between DANTE pulses, t_D=1 ms; G_z=18mT/m; gradient duration≈1 ms.
Table 2: T_2 weighted imaging protocols							
DIR	780/82 (ECG triggered)	160	15	5/100% sequential	N/A	2.5	DIR, Siemens product module, 2 pulse triggered
iMSDE	4000/ 59 (no ECG)	233	12	16/ no gap interleaved	2	3	G_z=20mT/m, G duration=4.4ms
DANTE	4000/82 (no ECG)	160	13	16/no gap interleaved	2	3	flip angle (FA) α = 3°-4°; Np=300; time duration between DANTE pulses, t_D=1 ms; G_z=18mT/m; gradient duration≈1 ms.
Table 3: Pd weighted imaging protocols							
DIR	780/13 (ECG triggered)	130	9	5/100% sequential	N/A	2.5	DIR, Siemens product module, 2 pulse triggered
iMSDE	4000/ 9.5 (no ECG)	247	12	8/ no gap interleaved	2	3	G_z=20mT/m, G duration=4.4ms
DANTE	4000/13 (no ECG)	130	9	16/no gap interleaved	2	4	flip angle (FA) α = 8°-9°; Np=150; time duration between DANTE pulses, t_D=1 ms; G_z=18mT/m; gradient duration≈1 ms.
Table 4: DANTE Prepared 3D GRASE							
DANTE	1000/15 (no ECG)	514	7, EPI factor=3	3 slab/no gap interleaved	1	3	flip angle (FA) α = 13°-15°; Np=72; time duration between DANTE pulses, t_D=2 ms; G_z=18mT/m; gradient duration≈2 ms.

Results: *Imaging comparison between DANTE, DIR and MSDE prepared 2D TSE*

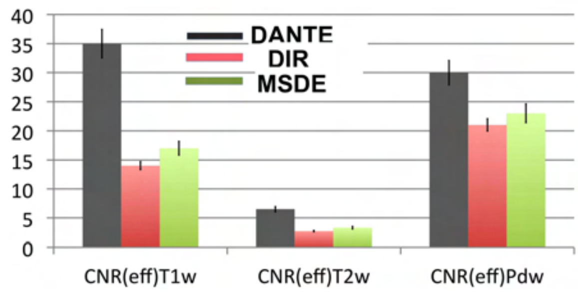

Fig. 2. Effective CNR comparison between DANTE and the conventional methods

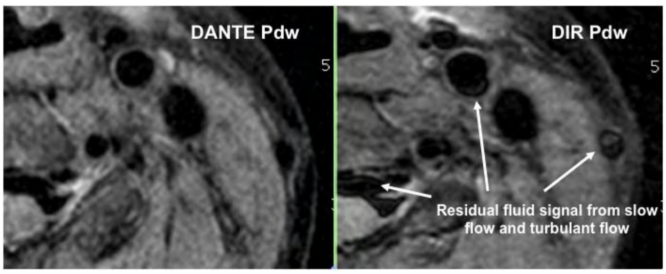

Fig. 3. Residual fluid signal from slow flow and turbulent flow effect

Fig 2. shows that there is in general about 50-100% effective CNR improvement as DANTE is compared with conventional methods. As shown in Fig. 3, DANTE may be more robust for slow flow and turbulent flow effects than conventional methods since progressive saturation of flowing spins is insensitive to spin velocity (above a low threshold). In Fig. 4, by employing 3D GRASE with its higher signal acquisition efficiency compared with 2D TSE, the averaged imaging speed reaches as high as 6 sec/slice. The calculated CNR_{eff} is thus 40 $min^{-1/2}$.

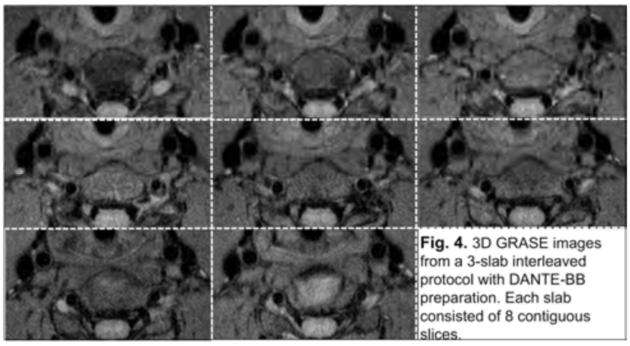

Fig. 4. 3D GRASE images from a 3-slab interleaved protocol with DANTE-BB preparation. Each slab consisted of 8 contiguous slices.

Conclusions The improvement of the DANTE method over the existing methods is considerable in T_1, T_2 and Pd weighted 2D imaging. DANTE may be adapted as a BB module for 3D BB acquisition.

Acknowledgements and References We thank Dr Matthew Robson for helpful suggestion and NIHR Oxford Biomedical Research Centre for grant funding. [1] Li L, Miller K and Jezzard P (2011) DANTE Prepared Pulse Trains: A Novel Approach to Motion Sensitized and Motion Suppressed Quantitative Magnetic Resonance Imaging, in revision. [2] Edelman RR, et al. (1991) Radiology. 181:655–660. [3] Wang et al. (2010) JMRI 31(5):1256-63.