Spinal Cord Structural Imaging with Suppressed CSF Signal Using DANTE Pulse Trains

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Introduction: Multi-contrast fast spin-echo (2D FSE or 2D TSE) techniques, such as T_1 weighted image (T_1WI), T_2 weighted image (T_2WI) and proton density weighted (PDWI) imaging, offer the gold standard for pathology detection and classification in cervical spinal cord[1]. Despite its lack of multi-contrast, 2D multiple-echo data image combination (MEDIC) imaging is another effective cervical spine imaging technique that provides topographical information regarding extradural and intradural pathology. However, due to hyper-intense signal of cerebrospinal fluid (CSF) or CSF flow related artefacts, these conventional techniques are suboptimal in showing structure in the subarachnoid space, abnormalities of the nerve roots, intradural extramedullary tumors, compression, displacement of the thecal sac and spinal cystic lesions, particularly at the cervicothoracic junction.

DANTE (Delays Alternating with Nutation for Tailored Excitation) pulse trains are a rapid series of low flip angle RF pulses interspersed with gradients. It has been previously demonstrated that during the application of DANTE pulses, the longitudinal magnetization of flowing spins is largely attenuated relative to static tissue/fluid, whose longitudinal magnetization is mostly preserved[2]. Therefore, the contrast between spinal cord and CSF is maximized whilst maintaining the grey matter and white matter contrast. In this study, a multi-contrast CSF-suppressed sequence using a DANTE prepared 2D-TSE protocol was implemented and compared to non-prepared 2D-TSE and MEDIC sequences. Preliminary results demonstrate that metrics of contrast-to-noise ratio between spinal cord and CSF regions (CNR_{cord}) in DANTE-TSE images is improved by a factor of 2 when compared with images acquired with conventional approaches. Imaging quality may be significantly improved in sagittal images due to flow suppression effects from DANTE pluses.

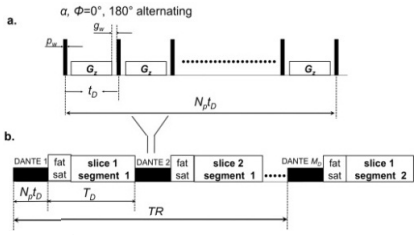

Fig. 1. DANTE multislice interleaved acquisition

Objective: We aim to demonstrate the possibility of employing a moving CSF suppressed DANTE-TSE multi-contrast imaging sequence for image quality improvement in the spinal cord when compared to conventional TSE and MEDIC sequences.

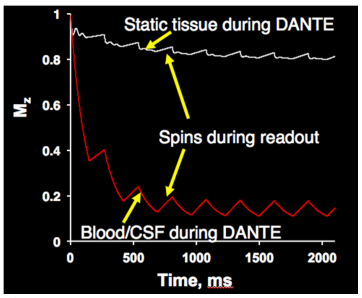

Fig. 2. Longitudinal Bloch simulation while DANTE applied.

Methods: The proposed DANTE imaging sequence is shown in Fig. 1, indicating both the DANTE preparation module itself, as well as the proposed imaging readout module, such as a TSE. N_p is the number of pulses applied in the DANTE module. Figure 2 shows the theoretical suppression of moving spins versus static tissue. A Siemens 3T Verio scanner was used for all experiments, along with a 12-channel head receive coil and a 4-channel neck coil. Five healthy volunteers (four male and one female, ages 24-36 years) underwent DANTE prepared and non-prepared 2D TSE T_1WI, T_2WI, PDWI and MEDIC imaging of the cervical spine. Resolution for all images was 0.6×0.6×3mm. Imaging speed for both T_1W DANTE-TSE and MEDIC data was 8 slices/min. The speed for non-prepared and DANTE-prepared T_2WI and PDWI TSE was approx. 4 slices/min. Two CNRs of a subject based on different standard deviations measured from both air and CSF regions are reported. Examples of regions of interests (ROI) in Fig. 3c were located on grey matter (GM), white matter (WM) and CSF in subarachnoid space. A ROI of the same size was chosen from a background region.

Results: Figure 3a shows comparison of PDWI and T_1WI DANTE-TSE with MEDIC and conventional 2D-TSE (Fig. 3b). It can be observed DANTE-prepared 2D-TSE is able to identify the ventral and dorsal nerve root and the border of the dura matter more effectively than conventional techniques because of the CSF suppression, whilst maintaining a comparable grey and white matter contrast to images obtained with the MEDIC sequence at the same location in the same subject. Quantification of CNRs in Table 1 demonstrates PDWI from DANTE-TSE maintain a comparable grey and white matter (GM/WM) contrast to images obtained from the MEDIC sequence with $CNR_{GM/WM}$ of 14.4 and 12.9, respectively. In addition, Table 1 shows that compared with the conventional MEDIC sequence, DANTE-TSE can achieve a significant improvement in image contrast between grey matter and CSF yielding twice the value of $CNR_{GM/CSF}$. Sagittal plane comparisons of DANTE-TSE versus conventional approaches in a healthy subject are shown in Fig. 4. Due to CSF suppression, the DANTE-TSE images (Fig. 4a,b,c) have a more homogenous appearance than the conventional techniques shown in Fig 4 d and e, which should help with accurate diagnosis of spinal lesions. **Discussion and Conclusions:**DANTE-prepared 2D-TSE multi-contrast imaging demonstrates improved CSF suppression and superior spinal cord visualization compared to conventional techniques for detection of intradural extramedullary structure whilst maintaining grey and white matter contrast. **Acknowledgements:** British Heart Foundation **References:** 1. Meindl T. et al. Euro Radiol. 2009; Clin Neurol Neurosurg. 2010; 2. Li L. et al. Magn. Reson. Med. 2012.

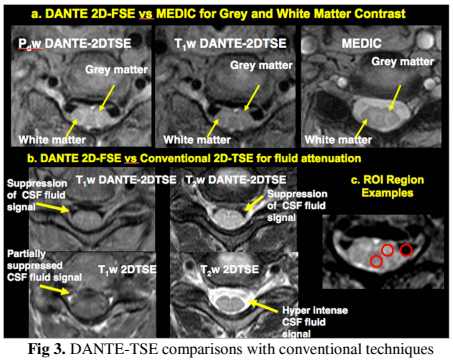

Fig 3. DANTE-TSE comparisons with conventional techniques

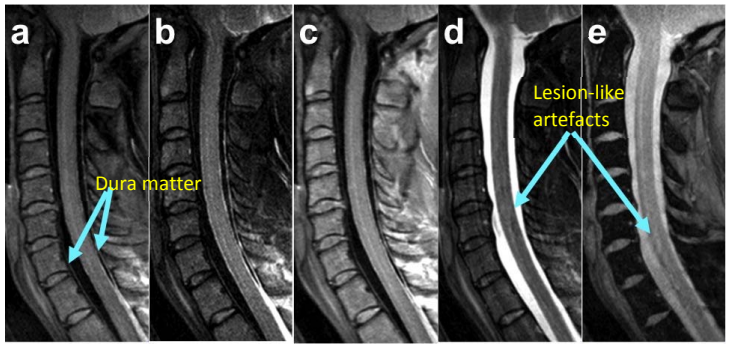

Fig. 4. Sagittal T_1WI (a), T_2WI (b), PDWI(c), from DANTE 2D-TSE. Non-prepared TSE T_2wWI(d) and MEDIC (e)

Table 1. CNRs against standard deviation of air (CNR_{air}) and CNRs against that of CSF (CNR_{CSF})

	MEDIC	DANTE-TSE PDWI		MEDIC	DANTE-TSE PDWI
CNR_{air} (GM / WM)	12.9	14.4	CNR_{CSF} (GM / WM)	4.2	5.2
CNR_{air} (GM / CSF)	37.6	65.1	CNR_{CSF} (GM / CSF)	12.2	24.2
CNR_{air} (WM / CSF)	50.5	50.7	CNR_{CSF} (WM / CSF)	16.4	19.0