Dual Contrast 3D-TSE, T2w and FLAIR imaging at 7.0 Tesla

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Introduction:

Multi slice T2w-TSE and FLAIR-TSE sequences are two of the most important techniques in neuro-radiology. The problem of partial volume effects and inherent CSF-inflow artifacts in FLAIR can be resolved by using a non-selective 3D-TSE acquisition technique with advanced refocusing pulse angle sweep [1]. A disadvantage of 3D TSE sequences with isotropic voxel size smaller than 1mm is the long scan time. High parallel imaging factors (SENSE, SMASH) have been proposed to accelerate the individual sequences. However, acquiring both high resolution T2w as well as FLAIR images in the same patient study results in unacceptable long scan times. Particularly at ultra high field strengths where improved signal to noise allows for higher spatial resolution this introduces practical limitations to resolution that can be reached. The aim of the present study is to develop a 3D TSE sequence that produces both a T2w and a FLAIR image in a single experiment within the scan time of a conventional 3D-FLAIR at 7T.

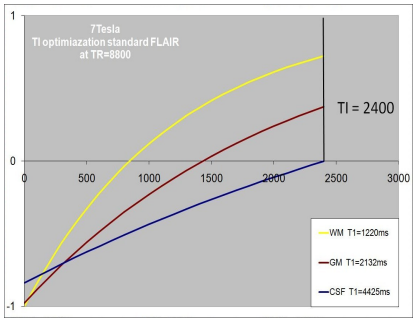

Figure 1: TI optimization standard FLAIR

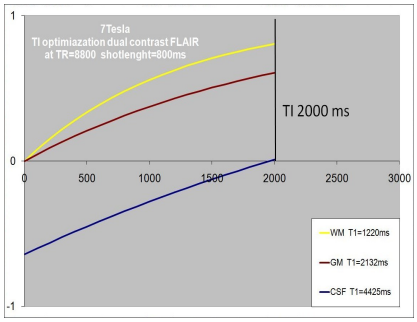

Figure 2: TI optimization dual contrast

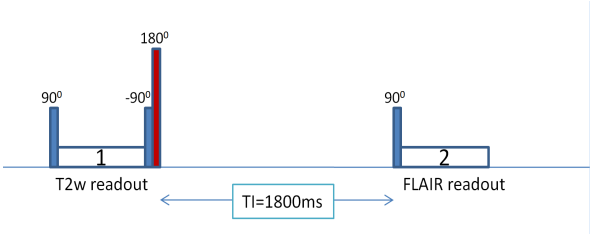

Figure 3: Dual contrast 3D-TSE

Methods:

Imaging was performed on a 7T scanner (Philips) using a 16 channel receive head coil with single channel transmit (Nova Medical). Figure 3 shows a schematic diagram of the proposed dual contrast 3D-TSE sequence. A sagittal non-selective 3D TSE sequence covering the whole brain at isotropic voxel size of 1 x 1 x 1 mm, zero-interpolated at 0.5 x0.5 x 0.5 mm, FOV 250, 360 slices, TR/TI/TE 8800/1800/390, turbo train-length 128, 2D-SENSE factor 6 (AP=2, LR=3.) Total scan time of 09:05 minutes.
The dual contrast sequence exists of a 90^0 excitation pulse followed by a 3D TSE read out with advanced refocus pulse angle sweep with nominal angle of 50^0 and TRAPS [1] enhancement at the end of the echo train. This produces a T2w image. A driven equilibrium pulse at the end of the sequence (DRIVE) is added to reset the remaining transverse magnetization of CSF back to the longitudinal axis. Short T2 components (e.g. grey and white matter) will not be reset by the DRIVE pulse after a pulse train length of 780 ms. The non-selective adiabatic inversion pulse given right after the DRIVE pulse is optimized to meet the adiabatic conditions at 7T in the presence of a relative in-homogenous B1 and B0 field. A second excitation pulse is given after the Inversion Delay TI to null the CSF component followed by a second TSE readout. This produces a FLAIR image. The repetition time of the whole sequence is 8800 ms , resulting in a recovery time after the second readout of 8800-(1800+780) = 6220ms. Simulations have been used to optimise the TI for CSF suppression for standard FLAIR and for dual contrast TSE after T2 mixing time of 780 ms over the first 3D TSE readout. (fig. 1 and 2). T1 relaxation times for GM, WM and CSF are taken from the literature [2]. T2 relaxation times are set to 80, 60 and 3500 for GM, WM and CSF respectively. The effect of the RF sweep has not been taken into account in the simulated results.

Results and discussion:

Dual Contrast 3D-TSE T2w/FLAIR at isotropic voxel size has been implemented successfully at 7T. Excellent T2 weighting on the first readout as well as FLAIR weighting on the second readout is shown in figure 4. The contrast simulation of CSF suppression shows an optimum TI at 2000ms. In-vivo results shows an optimum at 1800ms with 780ms 3D TSE readout time with driven equilibrium reset pulse. The discrepancy of the in-vivo and simulated results for CSF suppression in the second readout may be due to loss of phase coherence of CSF caused by flow over the shot length of the first readout (T2w) resulting in an incomplete inversion of CSF.

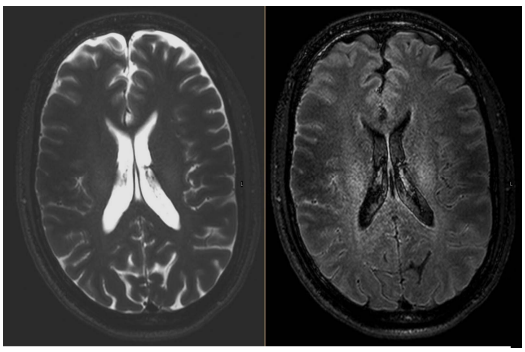

Figure 4: In-vivo dual contrast 3D TSE (MPR)

Conclusion:

Dual contrast TSE has the potential to be a new acceleration technique for clinical examinations. Especially at high field, this allows increased spatial resolution in clinical acceptable scan times. Clinical studies have to be performed to validate the technique for general neuro-applications. It also should be noted that the same dual contrast technique can be applied to 2D and multi-slice applications in case a full 3D examination would result in a prohibitive long acquisition time.

References:
[1] J. Hennig et al, Multi echo sequences with variable refocusing flip angles: Optimization of signal behavior using smooth transitions between pseudo steady states (TRAPS) *Magn Reson Med 2003;49:527-535*
[2] Rooney WD et al, Magnetic field and tissue dependencies of human brain longitudinal 1H2O relaxation in vivo. *MRM vol. 57*