Double Inversion Recovery MRI with Fat Suppression at 3T and 7T

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Introduction: Double Inversion Recovery (DIR)[1] MRI combines two inversion pulses in order to simultaneously suppress signals from tissues with different longitudinal relaxation times. In the brain, DIR allows to selectively image gray matter (GM) by nulling the signal from white matter (WM) and cerebrospinal fluid (CSF)[2] at the time of the excitation pulse. Additionally, DIR offers a flexible method of contrast alteration that has the potential to improve brain segmentation. Imaging GM structures is important in the study of many neurological disorders such as Alzheimer's disease[3], epilepsy[4] and multiple sclerosis[2]. The loss of SNR due to the longitudinal magnetization preparation can be counteracted by the implementation of DIR on high field scanners[5]. This requires, however, a careful adaptation of pulse parameters and fat saturation techniques. The aim of this study was to develop 2D and 3D DIR with fat saturation at 3T and 7T.

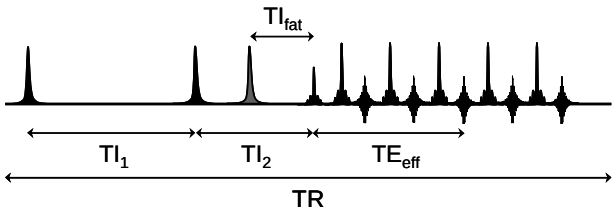

Figure 1. The DIR TSE sequence with csFatIR.

Material and methods: The experiments were performed on phantoms and healthy volunteers at 3T and 7T scanners (Siemens Medical Solutions, Erlangen, Germany) using a Siemens 8-channel, and a 24-channel phased-array head coil (Nova Medical Inc, Wilmington, MA, USA) respectively. A standard Turbo Spin Echo (TSE) sequence was combined with a DIR preparation and a chemical shift selective inversion (csFatIR) for fat suppression (see Figure 1) using non-selective adiabatic hyperbolic secant pulses. All adiabatic inversion pulses have a bandwidth-time-product of $T_p\Delta\nu = 15.26$, with T_p the pulse duration and $\Delta\nu$ the bandwidth. These parameters were optimized empirically on phantoms simulating tissues and then applied on brain in vivo: **At 3T**, **DIR** T_p = 12 ms, $\Delta\nu$ = 1.27 kHz; **csFatIR** T_p = 30 ms, $\Delta\nu$ = 508 Hz. **At 7T**, **DIR** T_p = 10.24 ms, $\Delta\nu$ = 1.5 kHz; **csFatIR** T_p = 14 ms, $\Delta\nu$ = 1.1 kHz. Large bandwidths for DIR were first adjusted to obtain a maximum suppression of the chosen tissues. The bandwidth of csFatIR was adjusted subsequently to optimize fat suppression while affecting the water signal as less as possible. For fat suppression, the frequency shift was -430 Hz at 3T and -1 kHz at 7T. At **3T**, the parameters for the **2D sequence** were: TE 68 ms, voxel size 0.94×0.94×4 mm^3, TA 2:56; for the **3D sequence**: TE 84 ms, voxel size 0.94×0.94×3 mm^3, TA 11:58. At **7T,** the **2D sequence** parameters were: TE 65 ms, voxel size 0.77×0.75×4 mm^3, TA 1:55; for the **3D sequence**: TE 88 ms, Voxel 0.77×0.75×3 mm^3, TA 11:58. The TR was 5 s and the ETL was 21 for all sequences at both fields. The TIs are given in Table 1.

Results and discussion: Selected 2D and 3D axial images obtained at 3T and 7T from a healthy volunteer are presented in Figure 2, both for WM+CSF and GM+CSF suppression. The standard fat saturation (FatSat) is acceptable at 3T but inefficient at 7T. At both fields, especially at 7T, the fat signal is better suppressed by a csFatIR, than by the FatSat method. The frequency bandwidth and location of each pulse need to be adjusted carefully in order to avoid mutual interaction of the suppression methods. For WM+CSF suppression in 2D, the contrasts between GM and CSF or WM are similar at 3T and 7T (SNR_{GM}/SNR_{WM} is around 5). In addition, the acquisition time was 1.5-fold shorter and the spatial resolution was 1.5-fold higher at 7T than at 3T. For WM+CSF suppression in 3D, the contrast is slightly better at 3T.The loss of signal in the middle of the images at 7T is due to the increase of B_1 inhomogeneities of the imaging sequence and to the lower central sensitivity of the 24 channels array coil.

Suppressed tissues	TI_1	TI_2	TI_{fat}
WM+CSF - 3T	2100	470	90
GM+CSF - 3T	2170	670	90
WM+CSF - 7T	2180	550	310
GM+CSF - 7T	2270	770	310

Table 1. Inversion times in ms.

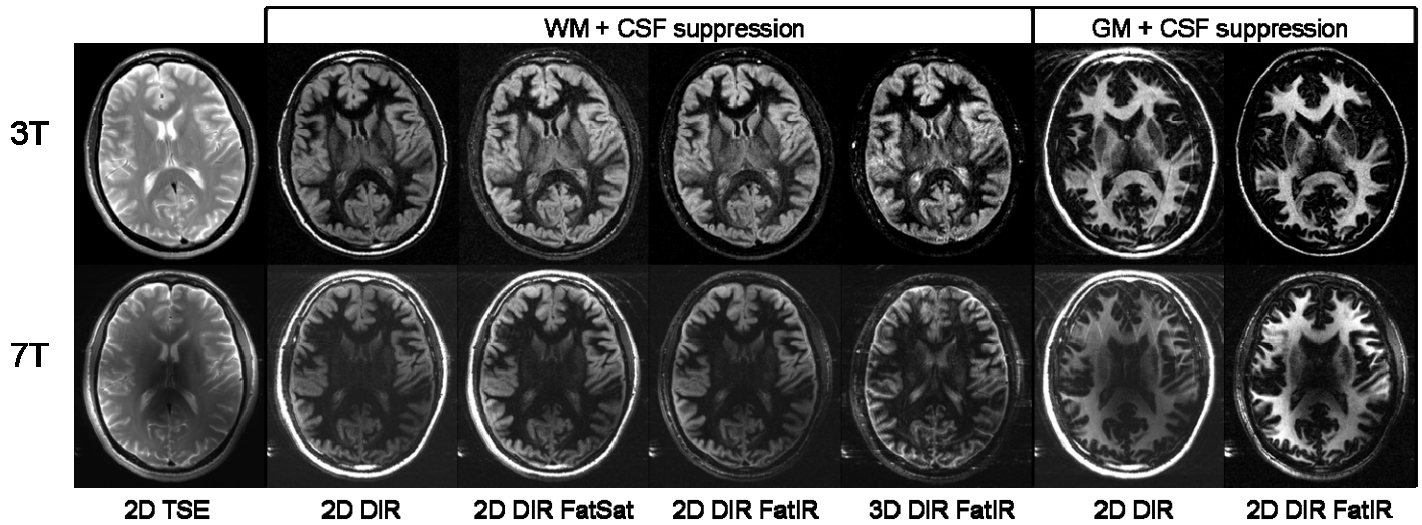

Figure 2. Selected 2D and 3D DIR TSE images acquired at 3T and 7T. The parameters of the sequence are given in the text.

Conclusion: This study demonstrates the feasibility of DIR with csFatIR at high field MRI. Future studies will focus on the improvement of image homogeneity at 7T and on the assessment of the cortex in neurological disorders.

References: 1. Bydder GM, Young IR, J Comput Assist Tomogr 1985. **2**. Pouwels PJ *et al.*,Radiology 2006. **3**. Frisoni GB *et al.*, J Neurol Neurosurg Psychiat 2002. **4**. Rugg-Gunn FJ *et al.*, Neuroimage 2006. **5**. Hu X *et al*, Annu Rev Biomed Eng 2004.

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