Whole Brain 3D-FLAIR Imaging at 7T

Eberhard Daniel Pracht[1], Daniel Brenner[1], and Tony Stöcker[1,2]

[1]German Center for Neurodegenerative Diseases (DZNE), Bonn, Germany, [2]Department of Physics and Astronomy, University of Bonn, Bonn, Germany

Target Audience:

Clinicians and scientists who are interested in fluid attenuated inversion recovery (FLAIR) imaging for lesion detection at ultra-high field.

Purpose:

FLAIR imaging is one of the most important methods for brain lesion detection but hampered at ultra-high field (UHF) as various issues compromise image quality and scanning efficiency: Prolonged tissue T_1 relaxation times lead to a loss of T_2 weighting, B_1/B_0 inhomogeneities induce signal drop outs and/or insufficient suppression of unwanted tissue components, and SAR limitations reduce scanning efficiency. UHF (7T) has become an increasingly important modality for neuroscience applications, however, the lack of decent FLAIR imaging may require subject-rescan at lower field (3T). In this work we propose a dark-fluid imaging approach based on an optimized double inversion magnetization preparation [1], combined with a SAR efficient vFA-TSE imaging module [2, 3]. Using this technique we were able to acquire FLAIR images with similar dark-fluid T_2 contrast, as the "gold standard" at 3T.

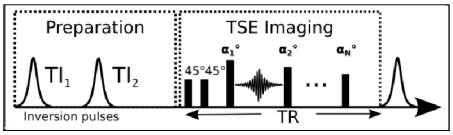

Figure 1: *Dark-fluid DIR sequence schematically: Double inversion preparation followed by a vFA-TSE imaging module.*

Methods:

Imaging experiments were performed on a MAGNETOM 7T scanner (Siemens AG, Healthcare Sector, Erlangen, Germany) using a 32 channel head coil (Nova Medical, Wilmington, USA). For SNR and image quality comparison a standard 3T FLAIR scan was acquired as well (MAGNETOM Skyra; 32 channel head coil, Siemens). For 7 Tesla FLAIR imaging an optimized variable flip angle (vFA) DIR-TSE was used (see Fig. 1). The inversion times were adjusted to suppress CSF, while simultaneously reducing T_1 weighting in the resulting images (see Fig. 2, right). To guarantee a homogenous inversion over the whole brain HSN pulses (N=6) were implemented [4]. For fat suppression a water excitation based on a 1-1 binomial pulse was used. Furthermore, to keep scan time as short as possible, optimized linear reordering schemes with elliptical scanning and 2D parallel imaging capability were used [5]. Before each imaging session B_1-mapping was performed using a vendor provided protocol and the transmitter reference voltage was optimized for cortical gray matter. Additionally, 3rd order B_0 shimming over the whole FOV was applied. Imaging was performed in a healthy male volunteer.

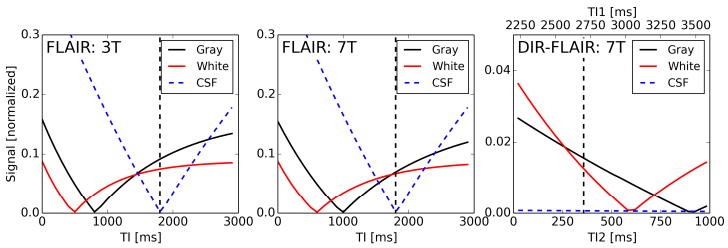

Figure 2: *Exemplary signal time courses:* ***Left****: Standard FLAIR sequence at 3T.* ***Middle:*** *7T: Due to prolonged tissue T_1 at UHF, T_2 weighting of WM/GM is lost when CSF signal is nulled.* ***Right****: Using the DIR approach T_1 weighting can be significantly reduced, therefore recovering T_2 weighting in the resulting images. The imaging module starts at the vertical dashed line.*

DIR-FLAIR sequence parameters at 7T: TR = 3200 ms, TI1/TI2 = 2000 / 279 ms turbofactor 234, 1x1x1 mm resolution, matrix size 256x256x176 (whole brain coverage), GRAPPA (R=2), yielding a total scan time of approximately 5:19 min. FLAIR sequence parameters at 3T: TR = 3200 ms, TI = 1800 ms, turbofactor 284, 1x1x1 mm resolution, matrix size 256x256x176 (whole brain coverage), GRAPPA (R=2), yielding a total scan time of approximately 4:37 min.

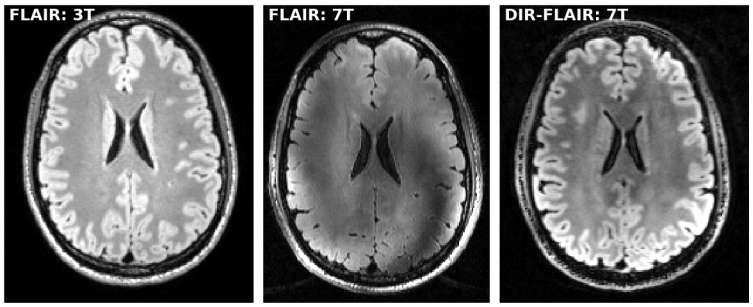

Figure 1: *Comparison of dark-fluid imaging at 3 and 7T in a healthy volunteer.*

Results:

Figure 3 shows FLAIR acquisitions at 3 and 7 Tesla. On the left the 3T standard FLAIR is depicted. Using the same sequence at 7T (only adapting TR from 3.4 to 5.7 s, to reduce T_1 weighting) results in images with no visible T_2 weighting. Furthermore, artifacts due to insufficient inversion over the brain arise. In contrast, applying the DIR sequence, optimized for dark-fluid imaging at 7T, solves the aforementioned issues: The DIR preparation reintroduces T_2 contrast. Additionally, no artifacts originating from incomplete inversion are visible. As can be seen in Fig. 4, even down to the cerebellum effective inversion can be maintained. The major drawback of this technique is the lower SNR compared to the standard single inversion, as the second inversion decreases the available magnetization for imaging. However, this SNR drop is almost compensated by the signal gain at UHF.

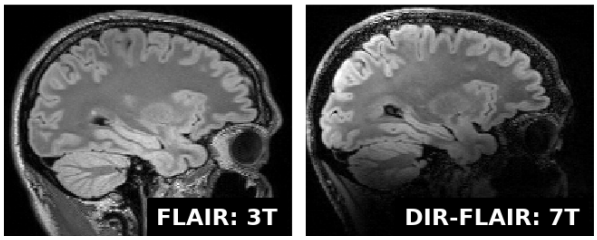

Figure 4: *Sagittal FLAIR images at 3 and 7T: Even down to the cerebellum inversion is working and generating a typical FLAIR contrast.*

Conclusion:

It was shown that high resolution, 3D whole brain dark-fluid imaging in short scan times is possible at 7T. The utilization of optimized inversion pulses allowed maintaining a high inversion efficiency over the whole brain. Therefore, the proposed method enabled the acquisition of homogenous, whole brain FLAIR images in acceptable scan times at 7T. The resulting images are identical in image contrast to 3T, and lack only slightly SNR compared to the standard approach at 3T. Now, even at UHF, a protocol for lesion detection is available. It allows scanning for brain anomalies in reasonable acquisition times and may enrich 7T imaging in clinical neuroscience.

References:

[1] Madhuranthakam et al. Magn Reson Med. 2012;67,81-8; [2] Pracht ED et al. Proc. Intl. Soc. Mag. Reson. Med. 2013; 21, 249; [3] Pracht ED et al. Proc. Intl. Soc. Mag. Reson. Med. 2014; 22, 996; [4] Tannus A., Garwood, M. NMR in Biomedicine 1997;10, 423–434; [5] Feiweier T. US Patent 7,728,588 B2