Assessment of multiple sclerosis at 7.0 T using high spatial resolution, fluid attenuated inversion recovery prepared susceptibility weighted fast spin echo imaging

Elena Maria Tovar Martinez[1], Katharina Fuchs[1], Fabian Hezel[1], Matthias Dieringer[1,2], Jens Wuerfel[3,4], and Thoralf Niendorf[1,5]

[1]Berlin Ultrahigh Field Facility (B.U.F.F.), Max-Delbrueck Center for Molecular Medicine, Berlin, Germany, [2]Working Group on Cardiovascular Magnetic Resonance, Experimental and Clinical Research Center (ECRC), Berlin, Germany, [3]Institute of Neuroradiology, University Medicine Goettingen, Goettingen, Germany, [4]NeuroCure Clinical Research Center, Charité University Medicine Berlin, Berlin, Germany, [5]Experimental and Clinical Research Center, a cooperation of the Charité Medical Faculty and the Max-Delbrueck Center for Molecular Medicine, Berlin, Germany

Target Audience: This work is of interest for engineers, basic researchers, clinical scientists and clinicians interested in susceptibility weighted imaging and neuroinflammatory diseases at 7.0 T.

Purpose: It has been shown that cerebral vascular alterations in Multiple Sclerosis (MS) and in particular the density of detectable periventricular veins can be used to differentiate MS patients from healthy controls [1]. Susceptibility weighted imaging (SWI) offers blood vessel contrast. The application SWI fast spin echo imaging (SWI FSE) [2] affords high spatial resolution and scan time reduction while depicting brain vasculature with the same efficacy as conventional gradient echo acquisitions [3]. However the hyperintense cerebrospinal fluid (CSF) signal dominates the dynamic range of FSE images, limits the dynamic range of brain tissue and obstructs the distinction from normal and pathological brain parenchyma. To improve contrast between vessels, lesions and normal brain tissue this work proposes a fluid attenuated inversion recovery susceptibility weighted fast spin echo approach. Its applicability for high spatial resolution imaging was carefully examined in phantom, volunteer and MS patient studies at 7.0 Tesla.

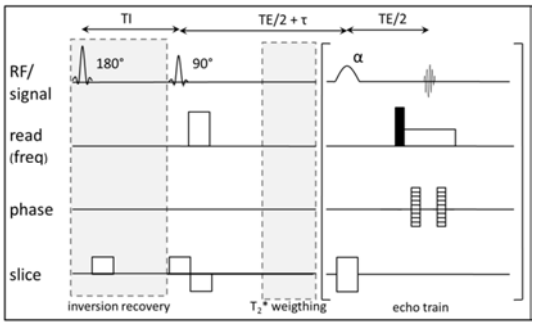

Figure 1 Basic scheme of fluid attenuated inversion recovery SWI FSE using the displaced UFLARE approach sequence.

Methods and Materials: To accomplish CSF suppression an IR module [4] was added to the displaced UFLARE (FSE) [2] together with a spoiler gradient to dephase any residual transverse magnetization produced by the inversion pulse. SWI contrast was accomplished by using an extra evolution time τ of 15 ms between the initial excitation pulse of the displaced UFLARE (SWI FSE) [2] and the first refocusing pulse as illustrated in Fig. 1 [2]. Considering a T_1 = 4425 ms for CSF at 7.0 T the inversion time (TI) was optimized in phantom studies (Fig. 2) to yield good cerebrospinal fluid suppression while conserving white matter and lesion contrast. Subjects were scanned on a 7.0 T scanner (Siemens Magnetom, Erlangen, Germany), using a 24 channel receive head coil (Nova Medical, Wilmington, MA, USA). The following imaging parameters were used: TR = 10 s, TE = 50 ms, TI = 2607 ms, ES = 5.39 ms, FA = 120°, matrix = 384x384 and resolution = (0.7x0.7x2.0) mm^3. For comparison, gradient echo SWI (SWI GRE) was applied. After data collection SWI GRE and SWI FSE data were post-processed [5]. Fluid attenuated inversion recovery (FLAIR) SWI FSE and SWI GRE were applied in normal subjects and in multiple sclerosis patients.

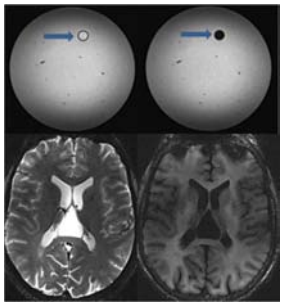

Figure 2 Phantom and volunteer magnitude images without (left) and with (right) fluid suppression.

Results: FLAIR SWI FSE provided images free of distortion and image quality degradation while achieving adjustable susceptibility weighting, high spatial resolution, enhanced blood vessel contrast and CSF suppression. The magnitude images of the FLAIR SWI FSE sequence in Fig. 2 demonstrate the fluid suppression and a good gray and white matter contrast. For blood vessel contrast comparison Fig. 3 shows post-processed minimum intensity projections derived from FLAIR SWI FSE and from conventional susceptibility weighted GRE. Venous vessels are more pronounced in SWI FSE including small venous vessels. Fig 4. shows an axial slice derived from FLAIR SWI FSE imaging in an MS patient with a neuroinflammatory plaque being clearly visible. It also shows an MS lesion of a patient detected with the FLAIR SWI FSE. The zoomed view of the lesion is a good demonstration that FLAIR SWI FSE presents iron enriched areas superimposed to MS lesion contrast. The images also demonstrate that FLAIR SWI FSE is insensitive to B_0 inhomogeneity related image distortions.

Discussion and Conclusion: Our results demonstrate the feasibility of a high spatial resolution, fluid suppressed, susceptibility weighted FSE imaging at 7.0 T and its application for imaging of neuroinflammatory diseases. FLAIR SWI FSE depicts similar brain vasculature versus conventional GRE with the advantage of providing hyperintense lesions and suppressed CSF. Our results are heartening and we anticipate extending our work to broader clinical studies for the assessment of periventricular venous density in MS patients together with the investigation of perivascular and parenchymal iron deposits.

References: [1] Sinnecker et al, MSJ 2012, Epub ahead of print; [2] Norris et al, MRM 1992, 27:142; [3] Tovar Martinez et al, Proc. ISMRM 2012, 421; [4] Hajnal et al, JC 1992, 506:13; [5] Haacke et al, MRM 2004, 612:8.

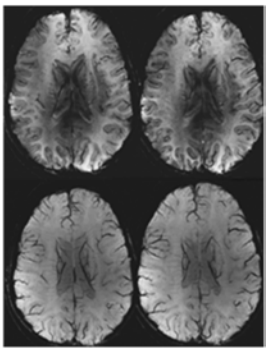

Figure 3 Examples of the SWI processed images for the implemented FLAIR SWI FSE (top row) and standard GRE (bottom row) at 7.0 T.

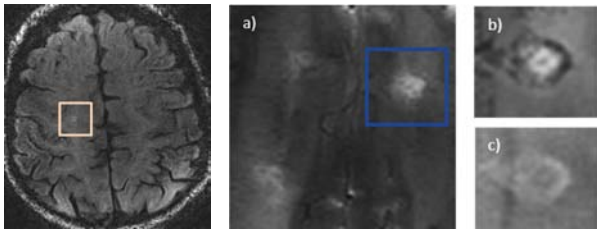

Figure 4 FLAIR SWI FSE image (left) of a volunteer with multiple sclerosis, plaque is clearly visible. MS lesion (center) as shown in a FLAIR SWI FSE image (a), the marked region is presented in zoomed details (right), where (b) shows the post processed FLAIR SWI FSE and (c) the filtered phase image. Neuroinflammatory lesions can be appreciated hyperintense (b,c), however, some lesions additionally are surrounded by a hypointense rim, possibly representing inflammation related iron deposits.