High spatial resolution susceptibility weighted fast spin echo brain imaging at 3.0 T and 7.0 T

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Introduction: Susceptibility Weighted Imaging (SWI) is a technique that uses the magnetic susceptibility differences between tissues to highlight small blood vessels with high anatomical detail [1]. SWI is of proven clinical value for stroke imaging and can be used to gain a better understanding of the pathogenesis of multiple sclerosis by the assessment of periventricular venous density. The clinical use of SWI for high spatial resolution whole brain imaging is challenged by scan time constraints due to the use of gradient echo based imaging modules [1]. Realizing this constraint this work proposes the use of susceptibility weighted fast spin echo imaging to afford a shortening in the acquisition time. To accomplish this goal a displaced ultra-fast low angle rapid acquisition and relaxation enhancement (UFLARE) imaging technique was implemented [2, 3]. Its applicability for high spatial resolution SWI was examined in phantom and volunteer studies.

Methods and Materials: Healthy subjects were scanned on a 3.0 T scanner (Siemens Verio, Siemens Healthcare, Erlangen, Germany), using an 8 channel head coil and on a 7.0 T scanner (Siemens Magnetom, Erlangen, Germany), using a 24 channel receive head coil (Nova Medical, Wilmington, MA, USA). The protocol included a localizer and a SWI displaced UFLARE. For comparison, a conventional GRE-SWI sequence was used. UFLARE acquires a train of refocused echoes that are independently phase encoded [2]. SWI contrast was accomplished by using an extra evolution time (τ) between the initial excitation pulse and the first refocusing pulse, as illustrated in Fig. 1. Any desired T_2* weighting can be introduced from zero on. T_2* weighting introduces unknown phase shifts due to B_0 inhomogeneities leading to destructive interference between the odd and even echo groups, resulting in severe image artifacts. Such interferences were eliminated by the displaced variant in which one echo group is shifted out of the acquisition window by using additional spoiler gradients along the read direction [4, 5]. The imaging parameters used in the protocol are shown in Table 1. After data collection both GRE and FSE images were post processed in the SWI standard way [1].

Table 1	3.0 T		7.0 T	
	FSE	GRE	FSE	GRE
FOV (mm²)	282 x 282	282 x 282	275x275	275x275
Matrix (AP x RL)	256 x 256	256 x 256	384x384	384x384
Resolution (mm²)	1.1 x 1.1	1.1 x 1.1	0.7x0.7	0.7x0.7
Slice thickness (mm)	2.0	2.0	2.0	2.0
Number of slices	40	40	10	10
TR/TE (ms)	3440/28	30/20	5800/36	26/14
Flip angle (°)	180	12	120	15
Scan Time (sec.)	129	290	181	251

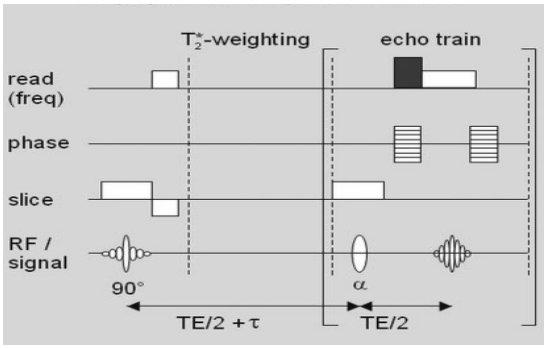

Figure 1 Basic scheme of displaced ultra-fast low angle rapid acquisition and relaxation enhancement (UFLARE) sequence.

Results: Using an evolution time (τ) of 20 ms at 3.0 T and 15 ms at 7.0 T the implemented displaced UFLARE sequence is able to create images where no significant image degradation is observed. With displaced UFLARE the acquisition time was reduced by approximately 35% versus GRE imaging (scan time: 2 min 9 sec for FSE vs. 4 min 50 sec for GRE) while achieving adjustable susceptibility weighting, high spatial resolution and an enhanced blood vessel contrast as illustrated in Fig. 2. For blood vessel contrast comparison conventional susceptibility weighted GRE images are shown. Fig. 2 also demonstrates that T_2* weighted UFLARE is insensitive to B_0 inhomogeneity related image distortions.

Discussion and Conclusion: The application of a displaced UFLARE for susceptibility weighted imaging affords high spatial resolution and scan time reduction. It depicts similar brain vasculature as compared to the conventional GRE acquisition though the point spread function of displaced UFLARE remains a concern. T_2 weighting inherent to displaced UFLARE echo images does not appear to diminish the usefulness of this fast imaging technique in a clinical setting and might be even exploited to further improve the image contrast for small vessel imaging. Our study showed very promising results in healthy subjects, we anticipate extending our work to clinical studies including stroke imaging and assessment of periventricular venous density in MS patients.

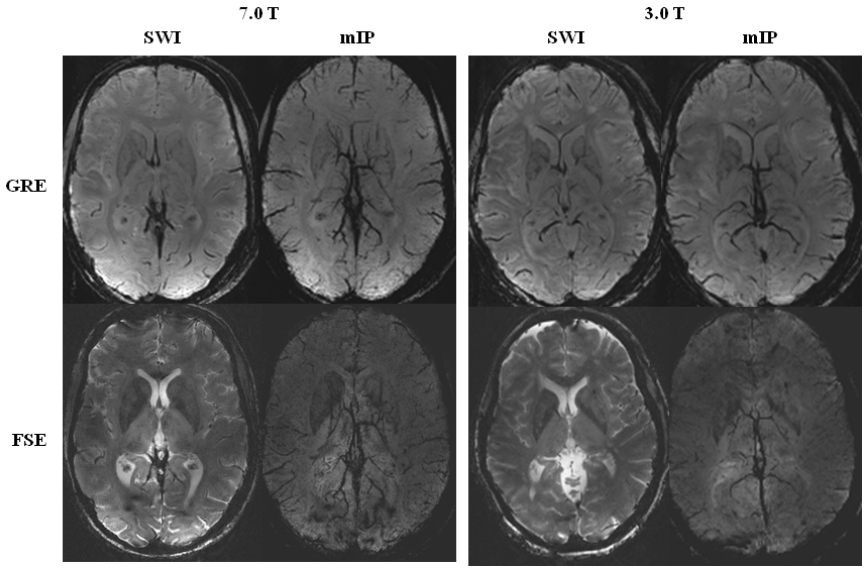

Figure 2 Examples of the SWI processed images and the corresponding mIP for the standard GRE and the implemented FSE at 7.0 T and 3.0 T.

References: [1] E.M. Haacke, et al., MRM, 2004 (52), 612-8. [2] D.G. Norris, MRM, 1991 (17), 539-42. [3] J. F. Utting, et al., IR, 2009 (44), 495- 502. [4] D.G. Norris, et al., MRM, 1993 (11), 921-924. [5] T. Niendorf, MRM, 1999 (41), 1189-98.