Susceptibility Weighted Imaging at 1.5T, 3T and 7T

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Introduction

Susceptibility weighted MR imaging (SWI) with high spatial resolution is able to visualize the cerebral venous vasculature down to vessel diameters of 100µm [1]. In recent years the field of application broadens and SWI was found to be suitable for the detection of (micro-) hemorrhages, arterial venous malformations, stroke and traumas [2]. Moreover, physiological changes in blood oxygenation due to the application of exogenous agents like carbogen [3] as well as caffeine were investigated. SWI acquisition at 1.5T is limited due to low SNR and would benefit from higher field strength. Therefore, SWI was performed at different field strengths and image quality compared for 1.5T, 3T, and 7T in this study.

Materials and Methods

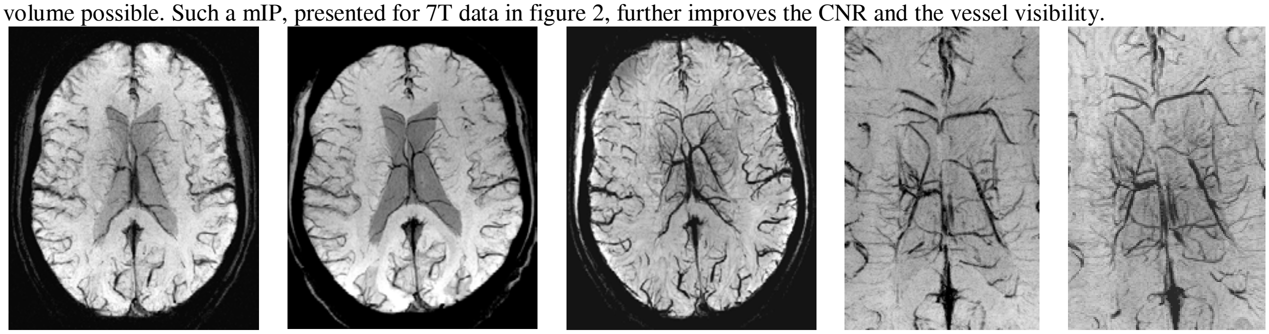
Susceptibility weighted data were acquired with a 3D fully velocity compensated gradient-echo sequence for one volunteer at magnetic field strengths of 1.5T, 3T and 7T. Therefor, the working SWI sequence from the 1.5T-system was compiled using the proprietary sequence developing environment (IDEA, Siemens Medical Systems, Germany, Erlangen) and transferred to the 3T and 7T MR-systems. However, at 7T the sequence was limited in the choice of the shortest TE due to the velocity compensation. For comparison of the results the acquisition parameters were roughly tried to adjust them to the 7T acquisition, in addition an optimized acquisition scheme for the 3T scanner was used (Table 1). Magnitude images were reconstructed from multi-channel data with the sum of squares method [4]. Homodyne filtering, the complex division in image space of the original data by the low-pass filtered data, was applied for each channel before calculating the final phase image [5]. The phase images were converted into a mask that was multiplied with the magnitude images to enhance the susceptibility related contrast. Finally, MR-BOLD venograms were obtained with minimum intensity projections (mIP) over a small stack of slices.

No.	MR-System	B_0	channels	TR	TE	FA	BW Hz/px	Acq.-Matrix	Partial Fourier	FOV	TA
1	Magnetom Sonata	1.5 T	8	57 ms	40 ms	20º	80	512x234x80	off	256x176x120 mm³	17.8 min
2	Magnetom Tim Trio	3 T	8	24 ms	14.1 ms	10º	80	512x214x80	off	256x160x120 mm³	6.8 min
3	Magnetom 7T	7 T	8	33 ms	17.8 ms	15º	80	512x214x80	off	256x160x120 mm³	9.4 min
4	Magnetom Tim Trio	3T	12	40 ms	24.5 ms	12º	40	512x352x144	6/8 6/8	230x158x115 mm³	19.0 min

Table 1: *Acquisition parameters of SWI data.*

Results

The venous vessel contrast increase with field strength is demonstrated in Figure 1(a-c). The depiction of vessels for optimized 3T is better compared to the initial results at 7T (Fig. 1(d,e)), which is due to the higher spatial resolution and lower pixel bandwidth at 3T (compare the 3rd and 4th acquisition protocols in table 1). Median filtering of SWI data [6] suppresses low-frequency structures and makes projections through the whole volume possible. Such a mIP, presented for 7T data in figure 2, further improves the CNR and the vessel visibility.



(a) (b) (c) (d) (e)

Figure 1: *Minimum intensity projections over 15 mm of one volunteer at (a) 1.5 T, (b) 3T and (c) 7T. The higher the field strength the better the visualization of smaller vessels. The ventricle is visible in (a) and (b) due to higher flip angles than the Ernst angle. The enlarged view of the central veins obtained by projection over 16 mm (d) for the optimized 3T and (e) 7T acquisition. In (d) veins are better delineated from the surrounding tissue than in (e) the corresponding section received at 7T.*

Discussion

Susceptibility weighed imaging and ultra high field strengths benefit from each other. The increasing extra vascular field inhomogeneities around veins at high field allow smaller vessels to be visualized with the same spatial resolution. Especially, the increase in SNR at higher fields can be spent to fasten the scan time with parallel imaging techniques such as GRAPPA or SENSE or to dramatically boost the image resolution. On the other hand SWI is not limited by SAR due to the low flip angles of around 10º. Moreover, the phase is independent of flip angle [7]. Currently, high field MRI is still under development with many problems such as B_1-inhomeneity and suboptimal coil-systems. In summary, SWI at 7T is promising, but today the 3T-systems are well-engineered that best results can be obtained with an optimized 3T acquisition protocol [6].

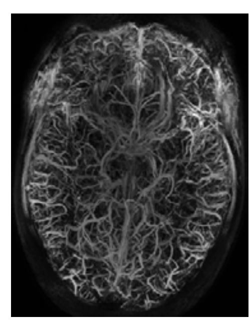


Figure 2: *mIP through the complete median filtered SWI volume. For a better visualization the contrast of the image was inverted.*

References: [1] Reichenbach JR et al., Radiology. 1997; 204(1): 272-277 [2] Sehgal V et al., J Magn Reson Imaging. 2005; 22(4): 439-50 [3] Rauscher A et al., Magn Reson Med 2005; 54(1): 87-95 [4] Roemer PB et al, Magn Reson Med. 1990; 16(2): 192-225 [5] Sedlacik J et al, Proc. of ISMRM. 2005: 241 [6] Kholmovski EG et al., Proc. of ISMRM 2006: 810 [7] Abduljalil AM et al, J Magn Reson Imaging. 2003; 18(3): 284-90