

## 3D High Resolution Susceptibility Weighted Imaging (SWI) Venography at 3T and 7T

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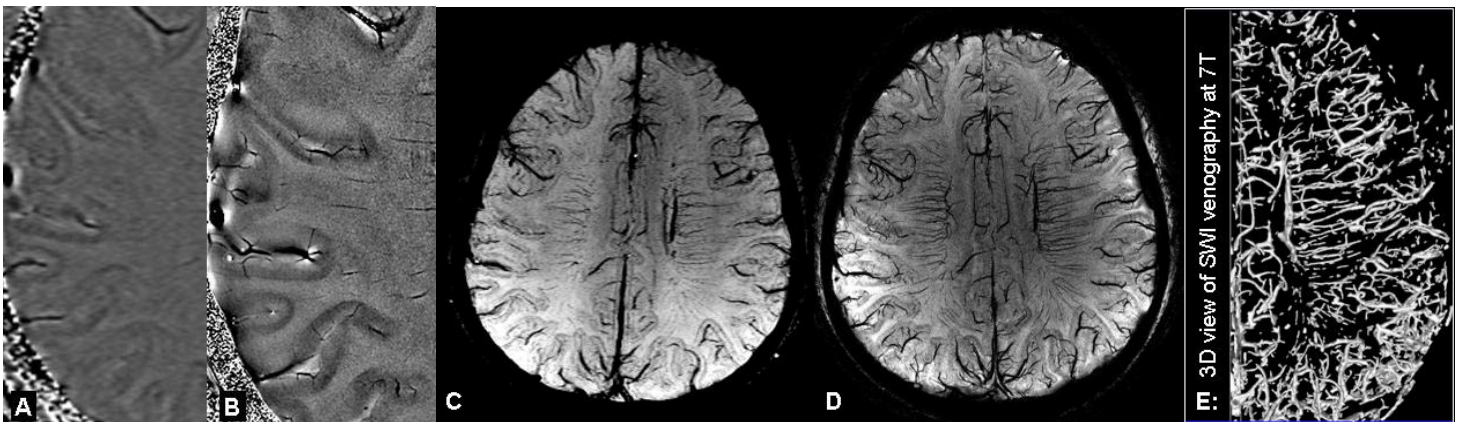
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**Introduction:** Susceptibility weighted imaging (SWI) is a 3D gradient echo sequence developed to enhance T2\* contrast from local susceptibility variations in tissue via the phase of the image (1,2). By exploiting the magnetic susceptibility of venous deoxyhemoglobin (as an intrinsic T2\* contrast agent), SWI provides high resolution venographic images. The susceptibility effects of deoxyhemoglobin are directly proportional to field strength (3). This allows for increased contrast and signal-to-noise ratio (SNR) at higher fields. This additional contrast and SNR allow for a better visualization of smaller and more numerous venous structures. This work demonstrates markedly improved quality of venography based on SWI at 7T as compared to 3T.

**Materials and Methods:** Four volunteers were run to optimize imaging parameters to best visualize veins using SWI on both 3T and 7T whole-body human MR systems (Siemens, Erlangen, Germany). For 7T scans, a 24-element head coil array (Nova Medical Inc., Massachusetts) comprised of two separate components: a birdcage like circularly polarized transmit coil and a 24 element phased array positioned on a close-fitting helmet-like form to maximize signal-to-noise ratio was used. For 3T scans, a 12-channel array head coil was used. SWI uses a fully velocity-compensated 3D gradient echo sequence. We varied TR, TE, BW and flip angle from 30-45ms, 13-26ms, 80-140Hz/pixel and 10-25°, respectively; for both 3T and 7T scans. Slice thickness was varied from 600μ to 1mm for 7T scans and 1mm to 2mm for 3T scans with in-plane resolution from 215μ to 430μ. The same high-pass filter was applied to the phase images for both the 3T and the 7T scans with the same phase multiplication factor of 4. The evaluation was based on SWI magnitude, phase and minimum intensity projection (mIP) images (4~8 slices from a 32-slice slab).

**Results:** Both SNR and contrast-to-noise (CNR) have shown marked increases in SWI venography at 7T versus 3T. The best contrast with appropriate SNR of venous structures was obtained at TE = T2\* of venous blood, specifically with TE=25 for 3T SWI and TE=15 for 7T SWI. The optimal flip angle at 3T and at 7T is roughly 20° and 15°, respectively. With an increase of TE, both contrast in the phase image and noise increase while larger flip angles decrease SNR significantly. As shown in Figure 1, compared to 3T, numerous additional small veins and venules are depicted on 7T SWI venography including small cerebral cortex veins (Fig 1B) or venules as a result of greatly increased SNR at 7T. In addition, compared to 3T where the best results were achieved with at 2mm thick slices and 430μ resolution, 7T SWI allows thinner slices (1mm and lower) and much higher resolution (215μ) but without losing much signal. The gray matter and white matter contrast is also better in both phase and mIP images on 7T compared to 3T.

**Discussion and conclusions:** Our results indicate that with substantial increases of SNR at ultra-high field, the capability of SWI venography to detect and distinguish small veins and venules in the brain has significantly improved. The extra boost in contrast obtained via phase multiplication has allowed SWI to fully take advantage of higher fields, such as 7T, for a high quality venography that is usually documented only in histological studies (4). The small cortical veins detected at 7T can be quantified to increase the spatial specificity in BOLD fMRI. High quality venography is important in discriminating the subtle abnormalities in various vascular diseases of central nervous system such as arteriovenous malformation, cavernous angioma, developmental venous anomalies etc.



**Figure 1:** Optimized SWI at 3T and 7T in a healthy volunteer - representative SWI phase images at 3T (A) and at 7T (B), mIP images (8mm thick) at 3T (C) and at 7T (D), as well as 3D venography from the entire slab (16mm thick) from 7T (E). This comparison was made with TR/TE/Flip angle of 45ms/25ms/20° and slice thickness of 2mm with resolution of 430μ at 3T and with TR/TE/Flip angle of 45ms/16ms/20° and slice thickness of 1mm with resolution of 215μ at 7T. Note that numerous small veins and venules are depicted on both phase (B) and mIP images (D) on 7T as compared to 3T (A and C). The small veins within cerebral cortex only depicted on 7T (C) can be used to increase the spatial specificity in BOLD fMRI.

**References:** 1. Reichenbach et al, Radiology, 204, 272, (1997); 2. Haacke EM et al, MRM 52, 612, (2004); 3. Abduljalil AM et al, JCAT 23,832, (1999); 4. Okudera T et al, Neuropathology 19,93, (1999).