Evaluation of the SWAN pulse sequence: a novel technique for Susceptibility Enhanced Imaging

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Purpose: Use of magnetic susceptibility effect as an image contrast is relatively new technique that has proven useful for evaluation iron containing tissues, cerebral microvasculature, and pathologic processes resulting in susceptibility changes (hemorrhage, metastasis, traumatic brain injury, metabolic disorders). The purpose of this work is to evaluate SWAN (T2Star Weighted ANgiography) a new susceptibility enhanced imaging sequence [1], and compare this technique to conventional gradient echo imaging.

Methods: SWAN is a relatively new technique that is sensitive to magnetic susceptibility. SWAN acquires multiple images at different echo times corresponding to different T2* weighting. SWAN employs flow compensated gradients to minimize spatial misregistration due to moving tissues and utilizes a simple sum-of-square weighted averaging for image reconstruction. This inherently achieves higher SNR than a single echo acquisition and chemical shift artifacts are further reduced with the deployment of high receiver bandwidth. The typical SWAN imaging parameters included TR =42ms, effective TE =24ms, flip angle = 20^0, receiver bandwidth = +/- 62.5 kHz, FOV = 24cm, imaging matrix =512x288 partial Fourier factor = 0.7, 60 slice locations at 2 mm thickness, flow compensation and parallel imaging (ASSET) acceleration factor of 2. An 8-channel phase array head coil was used in all exams.

We evaluated 10 patients who had both conventional GRE and SWAN scans obtained during the same clinical imaging session. 2D GRE images were acquired with a TR = 350 ms, TE=15 ms, flip angle = 20^0, receiver bandwidth = +/-16 kHz, FOV = 22cm, 4 mm slice thickness, imaging matrix = 256x192 with 1 excitation, flow compensation was used. Three neuroradiologists evaluated SWAN and GRE images on the following basis: 1) vessel conspicuity, 2) image quality [perceived SNR, resolution, artifacts, and 3) detection of iron deposition. In addition, the radiologists counted lesions for the seven patients displaying pathology for each technique. The radiologists were also asked to give their preference of sequence for each subject in terms of overall utility, ability to visualize veins and ability to visualize iron deposition. SWAN and GRE images were evaluated based on the following criteria: 1) lesion conspicuity, 2) image quality [SNR, resolution, CNR], 3) artifacts, 4) additional image features (vascular detail, ability to differentiate between arteries and veins, depiction of normal iron-containing structures e.g. subthalamic nuclei).

Results: For all evaluated criteria, SWAN was rated higher than GRE ($p < 0.001$, Sign Test). More lesions were consistently detected on the SWAN images ($p<0.001$, Sign Test). In every subject, each radiologist preferred SWAN to GRE for overall utility and ability to visualize veins and iron deposition.

Discussion: Susceptibility enhanced imaging using the SWAN technique is simple to perform, with relatively short acquisition times, providing high resolution whole head coverage, with ability of multi-planar reformatting. No post processing is required. SWAN can be performed at both 1.5T and 3T magnetic field strengths. Advantages of SWAN over GRE include better sensitivity to intraparenchymal susceptibility changes, with reduced artifactual image degradation at imaging boundaries (skull base, calvarium). Our results show that all lesions were seen as well or better using SWAN (**Fig 1**), which allows for better characterization and depiction of pathology not possible with conventional GRE imaging (e.g., perivascular plaque in MS (**Fig. 2**), biopsy tracts, etc.). SWAN also provides spectacular depiction of cerebral microvasculature, especially small veins. It is very sensitive to the susceptibility effects of deoxyhemoglobin. Small arterioles have high signal on SWAN, likely on the basis of paramagnetic effects of oxyhemoglobin, allowing characterization of small vessels as either venous or arterial. A minor drawback of SWAN is relatively long acquisition time compared to conventional GRE. Based on our early results, SWAN is more useful than conventional GRE for routine clinical imaging.
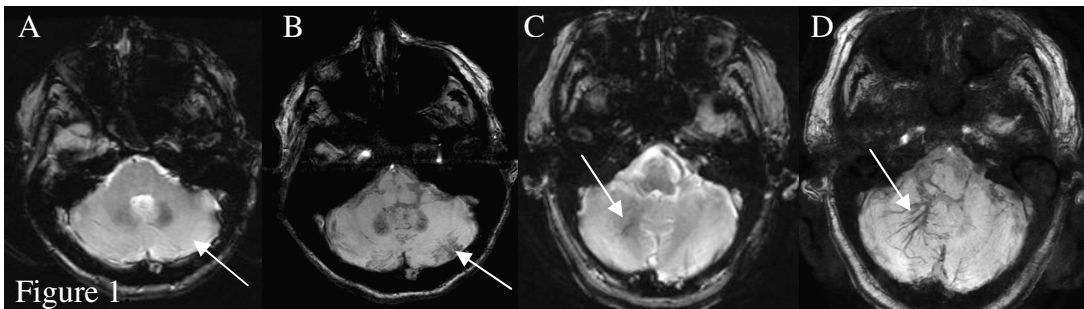

Figure 1: Imaging examples of GRE (images A and C) compared to SWAN (images B and D). Images A and B are from a patient with Siderosis where the old blood can be seen on SWAN (B), but not on GRE (note arrows). Images C and D are from a patient with a Venous Angioma that can be seen on SWAN (D), but is not as well visualized on GRE
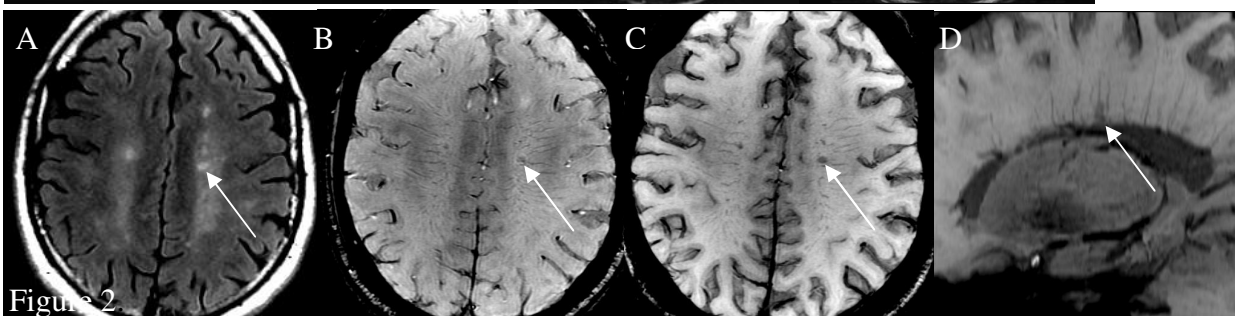

Figure 2: 40yo male with known multiple sclerosis. (A) T2 FLAIR image demonstrating several multiple sclerosis plaques. Axial SWAN images obtained using a 20-degree flip angle (B), and 30-degree flip angle (C). Note that the plaques are more visible on the 30-degree flip angle acquisition. (D) Sagittal reformatted SWAN MinIP showing the peri-venular distribution of a small MS plaque.

Reference: [1]. R.B. Annamraju, R. Venkatesan, A.T. VU, ESMRMB 2008, ePoster 482.