# Mind Over Matter: Susceptibility Enhanced Imaging of Brain Vasculature with SWAN

*By Lawrence Tanenbaum, MD, FACR and Tony Vu, PhD*

T2* or susceptibility enhanced contrast arises from local inhomogeneities of the magnetic field among tissues. T2* weighted contrast has been suggested to be a promising imaging technique for the enhanced imaging of brain vasculature. The sequence offers clinical properties for imaging high-resolution venous vascular network that allows the clinician to visualize venous structures and assess iron buildup in the tissue in neurodegenerative diseases. Imaging of major hemorrhages and microbleeding may assist clinicians in diagnosing cerebrovascular disease and broad spectrum of lesions.

The conventional 2D single TE gradient echo with sufficiently long echo time (~30 to 50 ms) is typically employed to achieve T2* weighted contrast. Low SNR, long acquisition time, and low spatial resolution capability of the 2D single TE method limits its clinical potential for susceptibility enhanced imaging. Other approaches involving 3D single TE gradient echo acquisition demonstrate some improvement in image quality but suffer similar SNR constraint, thereby, limiting the overall achievable spatial resolution.

## Description

3D T2-**S**tar **W**eighted **AN**giography (SWAN) combines a unique 3D T2*-based multi-echo acquisition with a special reconstruction algorithm. This technique has significant advantages over the conventional T2* sequences.

During each TR, SWAN captures multiple TE readouts at different echo times with varying degrees of T2* contrast. All echoes are then automatically reconstructed and combined as a weighted average by the postprocessing algorithm within SWAN.

## Technical advantages

The advantage of this GE-unique multi-echo approach is a significantly enhanced susceptibility effect, which can be translated into improved blood-tissue contrast. Since the SNR is directly proportional to the square root of the number of TE readouts per TR, the SNR in SWAN images is typically two to four times higher compared to a single echo T2* acquisition. 3D data sets can now be acquired with sub-millimeter spatial

resolution, without constraint by low SNR. In addition, chemical shift artifact is further reduced with multi-echo acquisition through the deployment of high receiver bandwidth, minimizing image blurring that is typical of T2* acquisitions.

Another advantage of the multiple TE readout is that the reconstructed SWAN image compiles not just one but the entire range of distinct T2* tissue contrasts. This unique property, combined with enhanced susceptibility sensitivity, high SNR, and ability to image small, sub-millimeter structures, makes SWAN an attractive technique for imaging small vascular structures and microbleeds, as well as large vessels and metal depositions in the tissue, at both the 1.5T and 3.0T field strengths. SWAN is a simple to use, fast, and robust technique that typically acquires a high-resolution 3D image of the entire brain in five minutes.

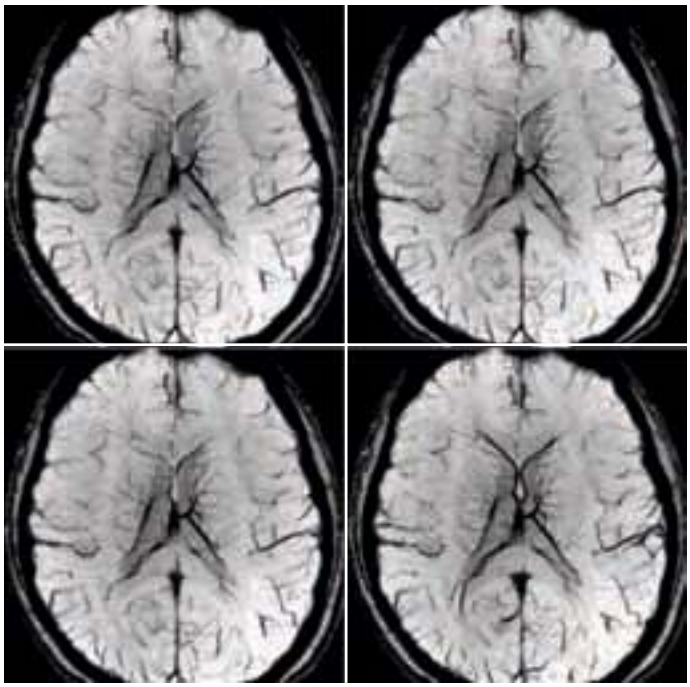

**Figure 1.** Representative minimum intensity projection images of 3D uni-polar 5-echoes acquisition obtained from a healthy volunteer. SWAN provides the enhanced visualization of venous vasculature.

**Protocol:**

Matrix size = 448x384
Flip angle = 20
Receiver bandwidth = +/- 62.5 kHz
FOV = 24 cm
TR = 40.7 ms
Effective TE = 25.4 ms
Number of echo = 5
$TE_i$ = 15.1-35.8 ms with 5.1 ms echo spacing
2X acceleration
Total acquisition time = 2:53 minutes

## Potential clinical applications

SWAN imaging provides enhanced visualization of susceptibility foci in tissue. This can help improve detection and characterization of:

- Vascular lesions characterized by hemosiderin deposition such as cavernous malformation and angiomatosis (Sturge-Weber Disease);
- Hemorrhage in acute and chronic stroke, useful in anticoagulative and thrombolytic therapeutic decision making;
- Hemorrhage in neoplastic disease assisting in tumor characterization and grading;
- Hemorrhage in chronic traumatic brain injury and suspected non-accidental brain trauma, improving assessment of disease presence and extent;
- Subcortical small vessel damage in vascular dementia;
- Iron deposition in deep brain nuclei, which can be associated with thalassemia, hemochromatosis or neuro degenerative diseases;
- Calcification in neoplastic lesions improving characterization; and,
- Calcification improving sensitivity to suspected chronic brain inflammatory disease.

Furthermore, SWAN imaging provides enhanced visualization of venous vasculature. This may assist with evaluation and characterization of:

- Vascular lesions such as developmental venous anomalies, capillary telangiectasias and arteriovenous malformations;
- Diseases with a perivenular distribution such as multiple sclerosis; and,
- The relationship of venous structures to neoplastic lesions.

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Lawrence N. Tanenbaum, MD, FACR, Director of MRI, CT and Outpatient/Advanced Development, Mount Sinai School of Medicine (MSSM). The school opened its doors in the fall of 1968 and has since become one of the world's foremost centers for medical and scientific training. Located in Manhattan, MSSM works in tandem with The Mount Sinai Hospital to facilitate the rapid transfer of research developments to patient care and clinical insights back to the laboratory for further investigation.

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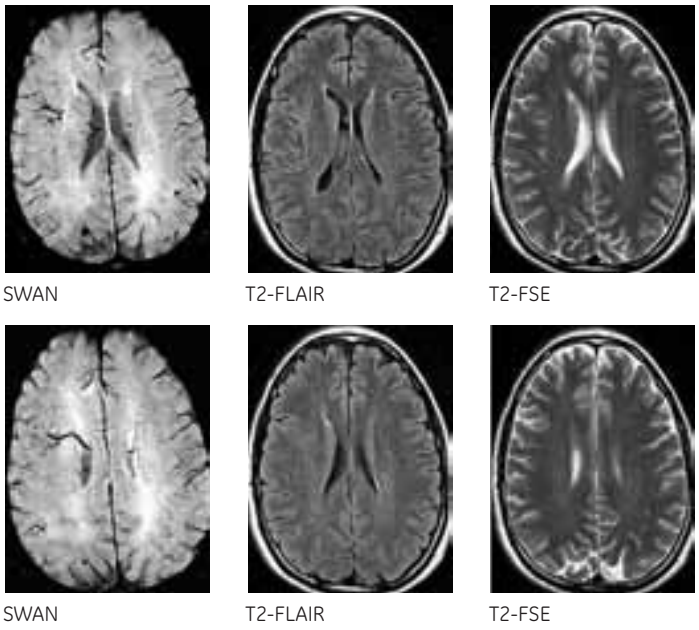


**Figure 2.** Venous anatomy and anomaly are well visualized with SWAN (left column). Note that the multiple rounded foci of susceptibility are better seen with SWAN than FSE (middle and right column).

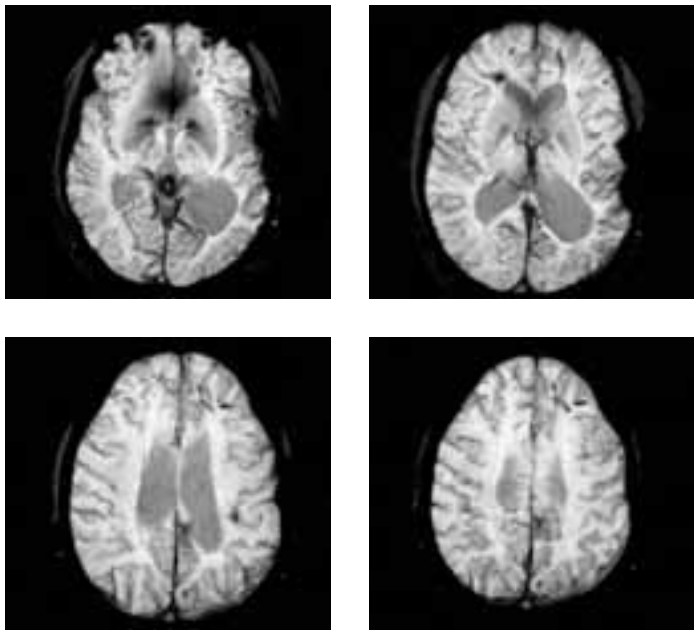

**Figure 3.** Traumatic brain injury. Note the superb depiction of hemosiderin in foci of traumatic/shear injury in these SWAN images.

## Summary

The broad clinical properties, high sensitivity with abundance of SNR, robust, reproducible performance, and relatively short scan times of SWAN make this GE-unique application relevant and attractive for most MR users. ■