

BASIC SCIENCE

TEMEL BİLGİLER

SUSCEPTIBILITY-WEIGHTED MR IMAGING: ADDED VALUE OF SUSCEPTIBILITY SIGNALS IN DIAGNOSIS OF HEMORRHAGIC LESIONS OF THE BRAIN

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ABSTRACT

Susceptibility-weighted imaging (SWI) is a relatively new high-spatial resolution 3D gradient-echo MR imaging technique that uses both magnitude and phase information. This technique exploits the magnetic susceptibility differences of various tissues or substances, such as blood products, iron, and calcification. It is particularly useful to visualize intravascular venous deoxygenated blood as well as extravascular blood products. Therefore, SWI provides additional diagnostic and prognostic data in the evaluation of a wide variety of neurologic disorders including various hemorrhagic lesions seen in traumatic brain injury, coagulopathic or other hemorrhagic disorders, occult vascular malformations, stroke, hypoxic-anoxic injury, neoplasms, and neurodegenerative disorders. We present a review with selected cases to illustrate and discuss the clinical usefulness of SWI in hemorrhagic lesions of the brain.

Key Words: Brain, vascular diseases, susceptibility-weighted imaging, gradient-echo, hemorrhage, magnetic resonance.

DUYARLILIK AĞIRLIKLIL MR GÖRÜNTÜLEME: BEYİN HEMORAJİK LEZYONLARININ TANISINDA DUYARLILIK SİNYALLERİNİN KATKISI

ÖZET

Duyarlılık Ağırlıklı MR görüntüleme magnitüd ve faz bilgisini birlikte içeren nispeten yeni yüksek rezolüsyonlu 3D MR inceleme tekniğidir. Bu teknikte kan ürünleri, demir ve kalsifikasyon gibi farklı dokuların veya yapıların manyetik duyarlılık farklılıklarından yararlanır. Özellikle intravasküler venöz deoksijenize kan yanısıra ekstrasvasküler kan ürünlerini görüntüleme yararlıdır. Bu nedenle, duyarlılık ağırlıklı görüntüleme travmatik beyin hasarı, koagülopatik veya diğer hemorajik bozukluklar, okült vasküler malformasyonlar, inme, hipoksik-anoksik hasar, neoplazmlar ve nörodejeneratif hastalıkları içeren birçok farklı nörolojik hastalığın değerlendirilmesinde ek tanısall ve prognostik bilgi sağlar. Bu yazıda duyarlılık ağırlıklı görüntülemenin beyin hemorajik lezyonlarında klinik yararlılığını göstermek ve tartışmak amacı ile seçilmiş vakaları içeren derleme sunuyoruz.

Anahtar Sözcükler: Beyin, damar hastalıkları, duyarlılık ağırlıklı görüntüleme, gradyan-eko, kanama, manyetik rezonans.

INTRODUCTION

Susceptibility-weighted imaging (SWI) is a relatively new high-spatial resolution, 3D gradient-echo (GE) magnetic resonance imaging (MRI) technique that exploits the differences in magnetic susceptibility of various tissues or substances, such as blood products, iron, and calcification (1,2). It uses both magnitude and phase information, thus creates new sources of contrast enhancement that

is significantly different from spin attenuation, T1-, T2- and T2*-weighting (3,4). This technique accentuates the paramagnetic properties of blood products such as deoxyhemoglobin, intracellular methemoglobin, and hemosiderin therefore it is very sensitive in the detection of intravascular venous deoxygenated blood as well as extravascular blood products (2,5).

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SWI has been reported to provide additional diagnostic and prognostic data that is often complementary to conventional MR imaging sequences used in the evaluation of various neurologic disorders, including traumatic brain injury, coagulopathic or other hemorrhagic disorders, occult vascular malformations, stroke, hypoxic/anoxic injury, neoplasms, and neurodegenerative disorders (1-28). In this review, we present selected cases to illustrate and discuss the clinical usefulness of SWI in hemorrhagic lesions of the brain.

Basic Principles of SWI

SWI is a long TE, high spatial resolution 3D fast low-angle shot (FLASH) MR imaging technique that maximizes sensitivity to susceptibility changes (1,2). It was originally described as high-resolution blood oxygen level-dependent (BOLD) venography (1,6,7). Haacke et al. (2) improved this technique and it is now referred to as SWI due to expanded applicability to study various disorders. The recent publications extensively describe the principles of SWI in depth (1-3,8). The underlying contrast mechanism is primarily associated with the magnetic susceptibility difference between diamagnetic oxygenated and paramagnetic deoxygenated hemoglobin that leads to a phase difference between regions containing deoxygenated blood products and surrounding parenchyma and results in signal intensity cancellation (1,3,5).

Briefly, SWI consists of both magnitude and phase information. After the imaging data are acquired, additional postprocessing steps are necessary to emphasize the loss of signal intensity caused by any susceptibility effects. The first step is to remove incidental phase variations in the images due to static magnetic field heterogeneities. As a second step, phase mask is created from the MR phase images and multiplied with the magnitude data to generate enhanced contrast magnitude image that is particularly sensitive to slow venous blood and other sources of susceptibility effects such as hemorrhage, calcium, and iron storage, thus allowing a significant improvement compared with T2*-weighted GE sequences. Finally, 9 to 12 mm thick minimal intensity projection (minIP) images are reconstructed that could further depict smaller caliber veins and the continuity of veins or

abnormalities across slices with attenuating the signal from the brain parenchyma (1-3,5,8,9). The steps of image reconstruction in SWI are shown in Figure 1.

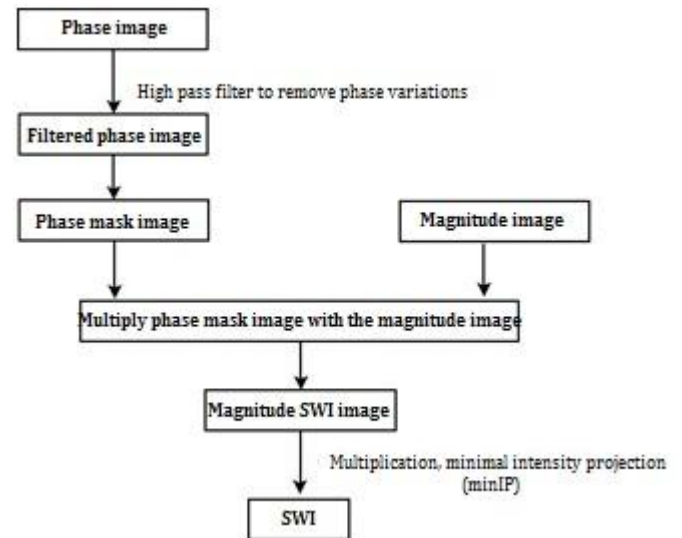


Figure 1. Postprocessing steps for image reconstruction in SWI.

The entire image processing is automated and the phase, magnitude, SWI, and minIP images are available on MR scanner platforms as shown in Figure 2.

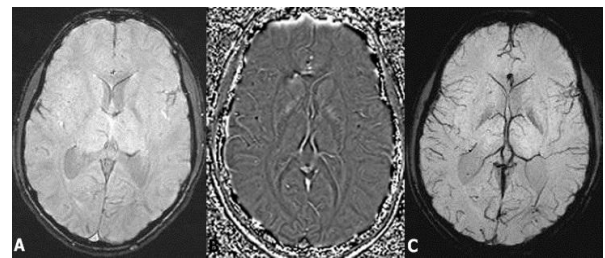


Figure 2. The phase (a), magnitude (b), and SWI minIP (c) images.

Susceptibility weighted imaging, using additional phase information to increase the sensitivity for paramagnetic tissues, was initially commercialized by Siemens (Malvern, PA) MRI. As SWI gradually replaced T2*-weighted GE in clinical use, different enhanced susceptibility imaging techniques were performed by other MRI vendors with slight modifications of this sequence (29). T2* susceptibility-weighted angiography (SWAN) MRI

was provided by General Electric (Milwaukee, WI), using multiple echo acquisitions and a special postprocessing reconstruction as weighted averaged sum of the individual images (29,30). SWAN does not use phase information, thus offers different contrast than SWI. Similarly, the susceptibility weighted images were reconstructed with different postprocessing technique to combine the phase information by Philips (Andover, MA) MRI and called as phase difference enhanced imaging (PADRE) (29). This technique enhances not only paramagnetic phase information, but any kind of phase information.

SWI sequences have some intrinsic disadvantages due to artifacts caused by undesirable sources of magnetic susceptibility at air-tissue interface, therefore limiting the evaluation of the posterior fossa and skull base (4).

Imaging Protocol

MR Imaging was performed using a channel phased array head coil on a 1.5 T clinical scanner (Espree; Siemens, Erlangen, Germany). The sequence consisted of a strongly susceptibility-weighted, low-bandwidth (80 Hz/pixel), long TE (TR/TE 49/40 ms, flip angle 20°) fully flow-compensated 3D FLASH sequence with slice thickness 2 mm, 56 slices in a single slab and matrix size 320 x 320. A TE of 40 ms was used to avoid phase aliasing and a flip angle of 20° was chosen to avoid nulling of the signal from pial veins located within the cerebral spinal fluid (CSF) (8). The acquisition time was 3.29 minutes.

Usefulness of SWI phase imaging in depiction of calcification or iron deposition

SWI is especially helpful in the detection of calcifications and microhemorrhages, which are both visualized as hypointense spots and cannot be differentiated by T2*-GE images (4,10). SWI filtered-phase images allow to discriminating calcium from hemorrhage and iron deposition on the basis of differences in diamagnetic versus paramagnetic susceptibility, respectively. This provides MR comparable to computed tomography (CT) in calcium imaging. Paramagnetic substances like blood products show positive phase shift in left-handed MR systems, such as Siemens. On the other hand, diamagnetic calcification induces negative phase shift opposite to paramagnetic substances (9-11,31), as demonstrated in Figure 3; a case of a histologically confirmed ependymoma

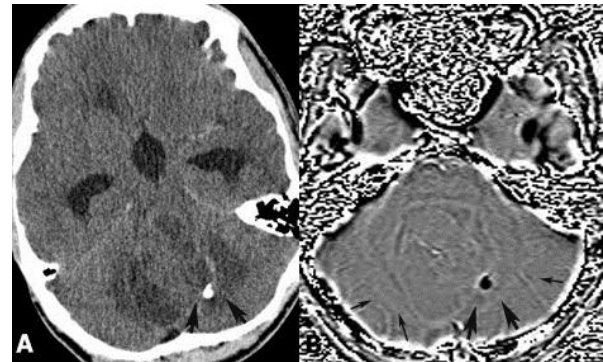


Figure 3. Ependymoma with intratumoral calcification (big arrows) on CT (a). SWI filtered-phase image (b) shows diamagnetic calcification as hypointense signal intensity (big arrows) opposite to the veins along the sulci (small arrows) appear as hyperintensities.

with intratumoral calcifications identified by CT. On SWI filtered-phase images, diamagnetic calcification shows hypointense signal intensity opposite to the veins along the sulci which appear as hyperintensities. As imaging systems might differ in terms of their handedness, and as phase images might be not uniformly windowed by all manufacturers, a more practical solution for determining whether a lesion that appears hypointense on SWI is due to hemorrhage or calcification might be to window or even invert the grayscale of phase images so that the lesion intensity can be compared with the intensity of veins. If both have similar intensities, the lesion is hemorrhagic, while the lesion is rich in calcium if the intensities are in opposite direction. Because the phase patterns are also dependent on the geometry of the lesions additional to the susceptibility difference between tissues, one should be very careful in differentiating blood from calcium by visual image information (11).

Clinical Applications of SWI in hemorrhagic lesions

SWI has been proved to be useful in increasing the sensitivity in detecting hemorrhagic lesions in various disorders, including traumatic brain injury, coagulopathies, and neoplasms, therefore can be helpful for clinical management and prognosis. The following sections describe additional imaging information provided by SWI in hemorrhagic lesions of the brain.

Cerebral microbleeds (CMB)

Cerebral microbleeds are relatively common

in the elderly population, particularly in patients with Alzheimer's disease (32). CMBs are observed in various diseases, such as chronic hypertension, cerebral amyloid angiopathy (CAA), cerebral autosomal dominant arteriopathy with subcortical infarcts and leukoencephalopathy (CADASIL), and cerebral vasculitis (9). CAA results in recurrent lobar microbleeds usually involving the cortex and subcortical white matter within the frontal and parietal lobes, whereas microhemorrhages both in deep basal ganglia and subcortical white matter or infratentorial location typically result from hypertensive or atherosclerotic microangiopathy (32). CT and conventional MR sequences usually fail to detect the cerebral microbleeds, which can be frequently visualized on T2*-weighted GE images. SWI with its higher sensitivity to magnetic susceptibility effects is much more sensitive than gradient images in identifying microbleeds, revealing up to 6 times more microbleeds than GE techniques (12,13). Cerebral microbleeds appear as black dots better displayed on minIP images. We evaluated a patient with hypertension shown in Figure 4 in which SWI revealed many microbleeds in deep basal ganglia and subcortical white matter and SWI detected many more microhemorrhages than T2-weighted sequences and also T2*-GE technique (not shown).

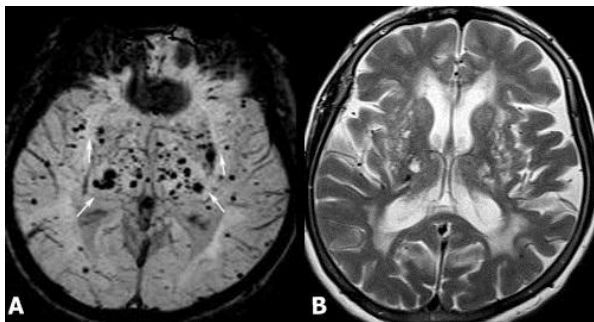


Figure 4. Hypertensive microbleeds. SWI (a) shows many microbleeds in deep basal ganglia and subcortical white matter (arrows) which are not visible on T2W image (b) in a patient with hypertension.

Trauma

CT is considered as the reference standard for the evaluation of hemorrhage in trauma patients. However, MR imaging is more effective than CT in identification and localization of smaller hemorrhages which is particularly helpful for the evaluation of diffuse axonal injury (DAI), often associated with small hemorrhages primarily in

the deep subcortical white matter due to a mechanical shearing and strain forces of injury. Evidence of DAI can improve the evaluation, treatment, and clinical management of patients with traumatic brain injury. T2*-weighted GE images have been shown to detect significantly more traumatic microbleeds than conventional MR sequences (14). However, Tong et al. (15,16) demonstrated that SWI is as much as 3-6 times more sensitive than T2*-weighted GE sequences in the detection of the number, size, volume, and distribution of hemorrhagic lesions in DAI. Numerous small hemorrhagic lesions were only detectable on SWI, although CT and conventional MR imaging sequences could identify larger hemorrhages.

Furthermore, these investigators (15) reported that the extent of hemorrhage in DAI was correlated with the initial severity of injury, the duration of coma, as well as the subsequent long-term outcome in a large group of pediatric patients. In Figure 5, SWI revealed very small parenchymal hemorrhages which were not visible on CT and barely visible on conventional MR imaging additional to extra-axial subdural hemorrhage.

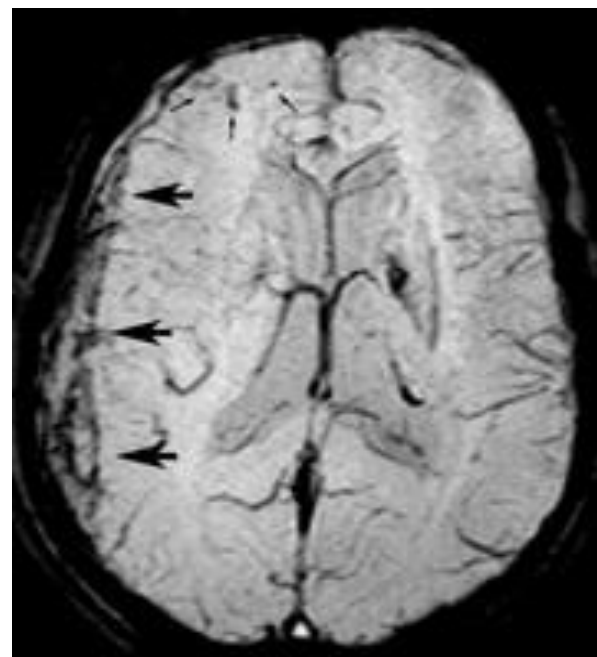


Figure 5. Trauma. SWI demonstrates small parenchymal hemorrhages in the right frontal lobe (small arrows) which were not visible on conventional MR imaging (not shown) additional to extra-axial subdural hemorrhage (big arrows).

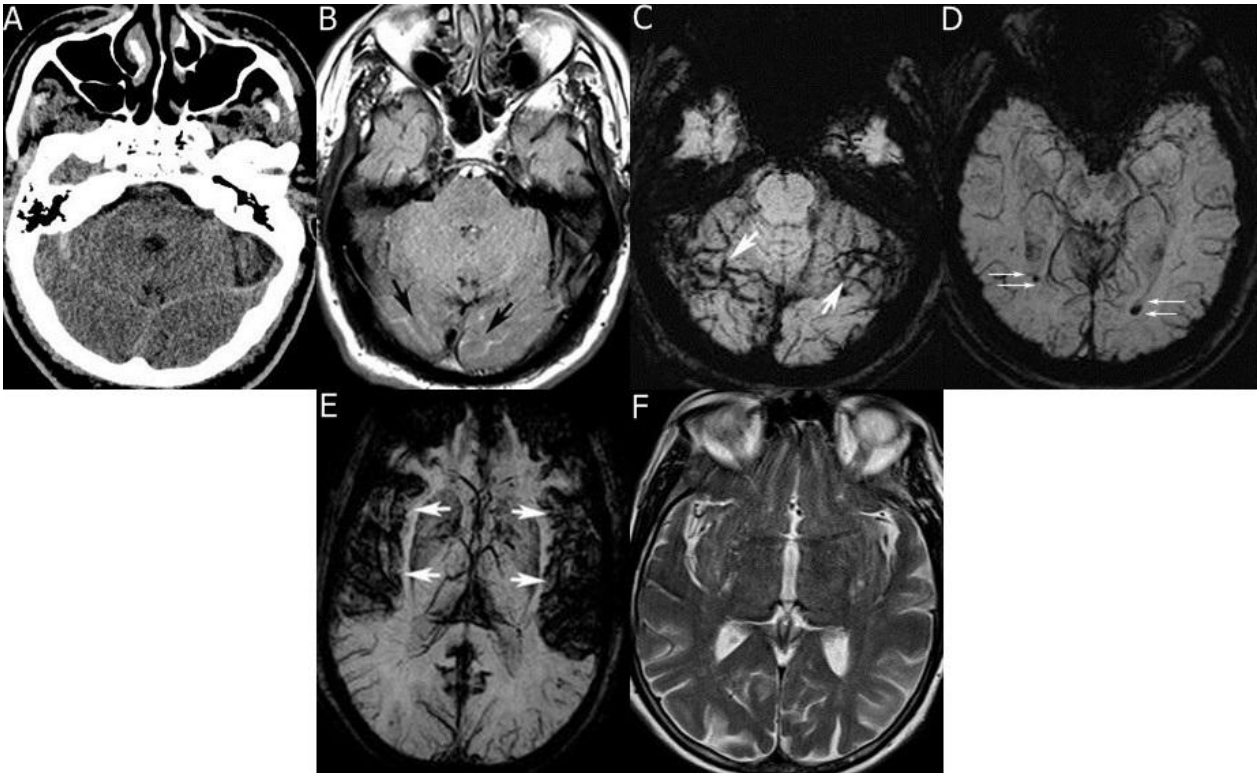


Figure 6. Nonaneurysmal SAH which CT examination (a) failed to identify. FLAIR image (b) shows hyperintense signal intensity (arrows) within the sulci mostly compatible with SAH. SWI (c) reveals hemorrhage within the sulci (arrows) with a sharper contrast than that on FLAIR and also intraventricular hemorrhage (d, small arrows) which was not detected on FLAIR. SWI (e) shows superficial hemosiderosis (arrows), barely seen on T2-weighted images (f).

Subarachnoid hemorrhage and superficial hemosiderosis

MR imaging is the most valuable method for diagnosis of subarachnoid hemorrhage (SAH), particularly in patients with a negative CT scan. CT is effective for acute SAH with a sensitivity of about 90%, but the sensitivity decreases with time and approaches 0% at 3 weeks. For the detection of SAH, the sensitivity of FLAIR was 100% versus 67% for CT and 36% for T2*-weighted images (33). However, subarachnoid hyperintensity on FLAIR images is not specific for SAH and may also be seen in other pathologies such as meningitis and meningeal carcinomatosis. SWI has been reported to be very sensitive to small amounts of SAH including subacute and chronic phases which are usually difficult to be identified with CT and/or conventional MR sequences and superior to CT in detecting intraventricular hemorrhage (9,17).

A case of nonaneurysmal SAH is shown in Figure 6 a-d. Initial CT examination was unable to

show SAH. SWI permitted visualization of hemorrhage within the sulci with unique morphology and a sharper contrast than that on FLAIR and intraventricular hemorrhage which was not detected on FLAIR. The signal intensity of SAH on SWI might be mistaken with veins for inexperienced individuals. It should be noted that veins are shorter and smooth with a uniform signal intensity, and do not perfectly follow the shape of the gyri while hemorrhage has a rough boundary with nonuniform signal intensity (10,17).

SWI can also reveal the pial staining of hemosiderin and ferritin in superficial hemosiderosis, barely seen on T2-weighted images, as shown in Figure 6 e, f.

Other types of Hemorrhagic Conditions

SWI can also be very helpful in the evaluation of other types of hemorrhagic lesions, such as those seen with coagulopathy, vasculitis or some infections. Coagulopathy can be presented with

either thrombosis or hemorrhage, and the extent of bleeding may be underestimated (5). Therefore, follow-up imaging studies may have an essential role in the clinical management of such cases. An example of this condition is shown in a patient presented with neurologic deficits after anticoagulation therapy in Figure 7.

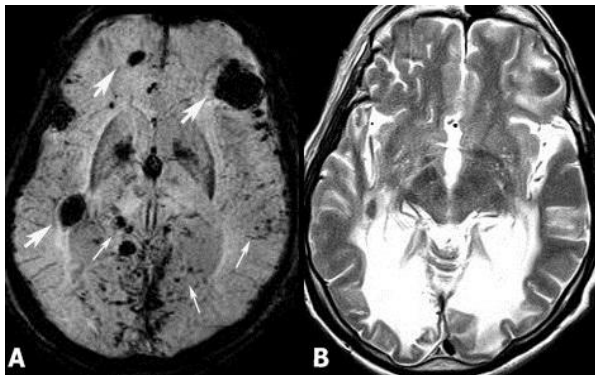


Figure 7. Coagulopathy. SWI (a) shows multiple small hemorrhages (small arrows) in the brain which were invisible on T2-weighted (b) and other imaging sequences in addition to large hemorrhagic areas (big arrows) after anticoagulation therapy.

SWI demonstrated numerous extensive small hemorrhages in the brain which were not visible on other imaging sequences in addition to large hemorrhagic areas. Similarly, SWI can reveal such extensive hemorrhages in the setting of vasculitis, which may also be missed with routine MR imaging.

Stroke

Diffusion-weighted imaging (DWI) is a powerful method to detect acute cerebral ischemia. SWI has been demonstrated as a complementary sequence in the assessment and work-up of acute stroke for several reasons. First of all, SWI is extremely sensitive in detecting hemorrhagic component within an infarct to distinguish ischemic and hemorrhagic stroke that may alter clinical management (Figure 8).

Earlier studies have reported that SWI is more sensitive in the detection of hemorrhage within acute infarct than CT and T2*-weighted GE imaging (19,20).

In acute arterial stroke, vascular occlusion may cause increased oxygen extraction and pooling of deoxygenated blood in the hypoperfused brain tissue. The increased visibility

of draining veins within hypoperfused areas may be suggestive of impaired cerebral blood flow in the penumbra around the infarct. Therefore, the combination of DWI and SWI can be used to predict the “mismatch” of diffusion-perfusion to assess tissue viability and to determine the necessity for further investigation with perfusion-weighted imaging (10,20).

SWI can demonstrate acute intravascular clot in the main branches of the cerebral arteries as MR angiography and also in distal branches which are not well visualized on MR angiography, thus help to direct thrombolytic treatment (18,20). Acute intravascular clots appear hypointense on SWI due to high deoxyhemoglobin content (10).

Hemorrhagic transformation is the most serious major complication of thrombolytic treatment with high mortality. SWI has the ability to detect spontaneous hemorrhagic transformation of ischemic stroke as well as hemorrhagic transformation after intra-arterial thrombolytic therapy with improved sensitivity earlier than CT imaging (10,20). Additionally, it has been suggested that SWI can predict the potential risk for hemorrhagic transformation before treatment by better identifying the number of microbleeds as shown in Figure 4 and Figure 8b (4). Furthermore, SWI also has the advantage to visualize prominence of veins surrounding the infarct region which were suggested as predictors for increased risk of hemorrhagic transformation in patients treated with thrombolytic treatment (20).

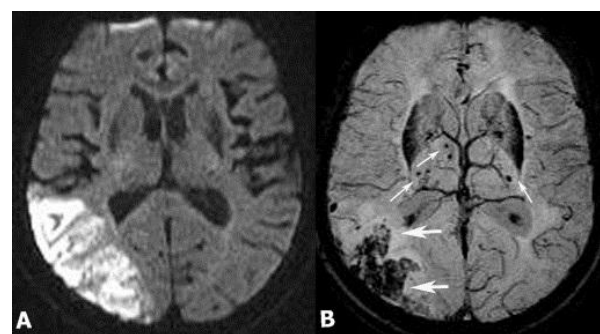


Figure 8. Acute hemorrhagic infarct. DWI (a) shows acute infarct in the right middle cerebral artery territory. SWI (b) detects hemorrhage (big arrows) within an infarct and microbleeds (small arrows) in deep basal ganglia.

Vascular Malformations

Vascular malformations such as cerebral

cavernous malformations (CCM), developmental venous anomalies (DVA), and capillary telangiectasias are usually difficult to identify without contrast medium administration and T2*-weighted GE imaging, because they mainly consist of small vessels with slow-flow. They are usually undetectable on conventional angiography unlike high-flow arteriovenous malformations, therefore these low-flow malformations have been described as “occult” (4,5,10).

T2*-weighted GE imaging is sensitive to detect small venous structures, however SWI with both phase and magnitude information improves sensitivity to detect small vascular structures which are invisible on conventional imaging (1,7,10). SWI has an essential role in the identification and characterization of vascular malformations. SWI has been found to be the ideal technique for screening patients with a high clinical suspicion of low-flow vascular malformations in a study of ten patients (7).

SWI has also been demonstrated to be superior to conventional time-of-flight (TOF) MR angiography for the depiction of small arteriovenous malformations with the advantage of allowing simultaneous visualization of different compartments (21). This technique can provide valuable information by the identification of small niduses, the exact location of the fistulous point, and the delineation of the venous drainage patterns.

Cerebral cavernous malformations

Cerebral cavernous malformations compose 10-20% of all cerebral vascular malformations (10). They occur in both sporadic form with a single lesion and familial form with multiple lesions (35). These malformations are often discovered as incidental findings, but commonly present with seizures, focal neurological deficits, and recurrent intracranial hemorrhages (4,10,35). The MR imaging findings of CCMs are variable, depending on the presence of hemorrhage and calcifications. Lesions that have previously bled can be easily identified on T2-weighted sequences and typically appear as mixed signal intensities, often described as “popcorn-like” in appearance, with a central reticulated core and a peripheral hypointense rim of hemosiderin. On the other hand, if these lesions are intact without hemorrhage, they may be almost invisible or may show a faint or ill-defined blush contrast

enhancement which is inconsistent and often nonspecific (5,10,35).

SWI is exquisitely sensitive to the phase changes caused by blood products. Therefore, CCMs appear very dark on SWI images as shown in a patient with multiple cavernomas in Figure 9 a, b. It should be noted that the actual size of the lesion is likely smaller than the imaging abnormality that is artifactually enhanced like the “blooming” of hemorrhages seen with any GE sequence (5). Moreover, early studies have suggested that SWI was more accurate than T2*-GE imaging in detecting CCMs (2,7). A study of 15 patients with familial CCMs reported that the sensitivity of SWI in identifying the number of CCM lesions was significantly higher than that of T2-weighted fast spin-echo and GE sequences (22). Therefore, SWI may be helpful to identify familial forms which are especially at high risk for hemorrhage and developing new lesions and should be referred for genetic evaluation.

Developmental venous anomalies

Developmental venous anomalies are the most common type (>60%) of cerebral vascular malformations and are often found incidentally (23). These malformations drain the normal brain parenchyma. They classically appear as a caput medusa consisting of a radially arranged venous complex which converging on a large draining vein. Although DVAs are typically asymptomatic, they are frequently associated with other vascular malformations, in particular CCM, which may be symptomatic (Figure 9b) (36). Reichenbach et al. (24) reported improved sensitivity of SWI for DVAs. SWI can show conspicuously deep medullary veins and draining vein that are hardly

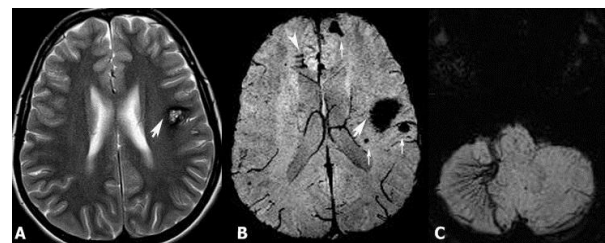


Figure 9. a-c. Cerebral cavernous malformation and DVA. T2-weighted image (a) shows typical CCM (arrow) on the left hemisphere. SWI (b) depicts additional 3 more CCMs (arrows). Only one of these lesions (arrow) is barely seen on T2-weighted image. SWI also demonstrates right periventricular DVA (arrowhead) accompanying CCMs. In another patient (c), typical caput medusa appearance of DVA is only seen on SWI.

visible on conventional MRI sequences without requiring contrast media Figure 9c.

Telangiectasias

Telangiectasias are smaller and less common than cavernomas and can occur as mixed cavernoma/telangiectasia lesions. These malformations may occur sporadically or may be associated with syndromes (e.g. hereditary hemorrhagic telangiectasia) or may manifest as a result of radiation-induced vascular injury. These malformations are usually asymptomatic, but more extensive lesions which cannot be identified with routine imaging, may present with subtle neurologic symptoms. However, SWI can easily detect these lesions with low signal intensity which are characterized by poor contrast enhancement and can therefore be missed on conventional MR sequences (4,5).

Brain tumors

Contrast enhancement, heterogeneity, edema, mass effect, cystic formation or necrosis, metabolic activity, and vascularity are important criteria of high-grade malignancy for the imaging-based grading of gliomas. Therefore, SWI can serve as an additional tool in the grading of cerebral neoplasms by enhancing the visibility of tumors with assessment of increased vascularity and detecting hemorrhage and calcification which cannot be visualized with conventional MR imaging (4,5,10,25).

Calcification is an important indicator in differential diagnosis of brain tumors and may imply a lower grade with indicative of slower growth. As mentioned before, phase images can be helpful to differentiate calcification from hemorrhage which cannot be definitively differentiated by other MR sequences (Figure 3).

One of the most important parameters for determining the grade of gliomas is based on angiogenesis of pathologic vessels, which signify the amount of vascularity. Christoforidis et al. (26) have observed increased identification of microvasculature in glioblastoma multiforme with the help of high-resolution T2*-GE images on 8T MR. Seghal et al. (25) have reported that SWI can better define internal architecture and boundary of tumors and detect vascular structures and blood products within tumors compared with conventional MR sequences as well as contrast-

enhanced T1-weighted images. Thus, SWI may be helpful guiding the clinical management of these cases. On SWI images, CSF is suppressed but parenchymal edema remains bright relative to the normal tissue, thus showing FLAIR-like contrast and improving delineation of tumor architecture, as shown in Figure 10. In addition, SWI clearly delineates the boundary and internal vascular structure of glioblastoma multiforme and different regions of the tumor and hemorrhage within the tumor are shown which are not visible even on contrast-enhanced T1-weighted images.

On the other hand, it can sometimes be difficult to distinguish hemorrhage from vascular structures due to the similar paramagnetic susceptibility effect particularly for inexperienced users. However, hemorrhage can be easily differentiated from veins with the administration of contrast agent (4,5,10). Blood vessels will change their signal intensity, whereas signal intensity in the regions of hemorrhage will appear unchanged. Contrast-enhanced SWI has also been proposed in distinguishing brain tumor recurrence from chemoradiation injury (27).

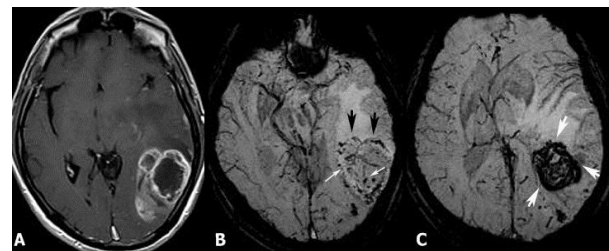


Figure 10. a-c Glioblastoma multiforme. Contrast-enhanced T1-weighted image (a) shows tumor with high-grade features. SWI (b, c) provides contrast combination of T2* effects and FLAIR. SWI (b) clearly defines the boundary and internal architecture of the tumor by detecting hemorrhage (white arrows) and increased vascularity (black arrows). In addition SWI shows different parts of the tumor in which the superior component (c) was more hemorrhagic (arrows).

High-field SWI

Higher field strengths, as expected, have the advantages of obtaining images with improved spatial resolution and increased susceptibility effects in venous structures or lesions, such as microbleeds and mineralization, with shorter acquisition times compared to low-field MRI (4,9). SWI has been used in the evaluation of neurologic disorders at 3T with excellent results (4,12,28). However, susceptibility-based signal loss and

image distortion due to artefacts at air-tissue interface or other sources of local field heterogeneity are much more severe with imaging at higher field strengths, caused by their increased sensitivity to susceptibility effects, therefore limiting the usefulness of this sequence particularly in the investigation of the posterior fossa and skull base (4).

Conclusion

It is our impression that adding SWI sequence as described in this review can improve the sensitivity of MR imaging in the detection of various hemorrhagic lesions. SWI interpretation will require some experience, but improvements in software technology will allow easier acquisition and increase in clinical use. Therefore, this sequence may be incorporated into the routine diagnostic imaging to provide useful complementary information in the diagnosis and potential treatment of hemorrhagic lesions.

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