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ORIGINAL ARTICLE

Role of magnetic susceptibility weighted imaging in evaluation of brain lesions

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KEYWORDS

SWI;
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Abstract *Introduction:* Susceptibility-weighted imaging (SWI) is a new method in MR imaging. SWI detects the signal loss created by disturbance of a homogeneous magnetic field; these disturbances can be caused by paramagnetic, ferromagnetic, or diamagnetic substances. There are many neurologic conditions that can benefit from this method.
Objective: To assess the role of magnetic susceptibility weighted imaging in evaluation of brain lesions.
Methods: The study was conducted on 30 patients with different brain lesions. Routine MRI study and SWI were done to all patients.
Results: The study included 30 patients with different brain lesions, including three patients with diffuse axonal injury, six patients with stroke, six patients with brain tumors, six patients with chronic microbleeds, five patients with venous malformations and venous thrombosis and four patients with extra-axial hemorrhage. In all patients SWI proved excellent demonstration of veins as well as bleeds.
Conclusion: SWI is valuable in the diagnosis of different brain lesions and should be included in routine assessment of the brain.

Abbreviations: SWI, susceptibility weighted imaging; BOLD, blood oxygen level dependent; MS, multiple sclerosis; DVA, developmental venous anomaly; MRV, magnetic resonance venography.

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1. Introduction

"Susceptibility-weighted imaging (SWI) is a new means to enhance contrast in MR imaging. MR imaging has already an overabundance of different approaches for investigational anatomic, functional, and metabolic imaging. Each method focuses on a new issue. SWI offers information about any tissue that has a different susceptibility than its surrounding structures such as deoxygenated blood, hemosiderin, ferritin, and calcium".[1] "SWI was originally called 'High-Resolution Blood oxygen level dependent (BOLD) Venography' which, as the name suggests provides an increased visibility of the

Table 1 Age and sex frequency of the studied 30 patients with brain lesions.

Age	Male	Female	No. of cases
< 10	2	1	3
10–	0	1	1
20–	0	2	2
30–	2	2	4
40–	1	2	3
50–	8	1	9
60–	2	1	3
70–80	5	0	5
Total	20 (67%)	10 (33%)	30

Table 2 Frequency of the studied patients according to the categories of brain lesions.

Categories	No. of cases
1. Trauma	3
2. Stroke	6
3. Chronic microbleeds	6
4. Tumors	6
5. Venous malformations and venous thrombosis	5
6. Extra-axial hemorrhage cases	4
Total	30

venous vasculature in the brain. SWI-based MR venography uses the fact that paramagnetic deoxyhemoglobin in veins causes a shift in resonance frequency between the venous vessel and the surrounding tissue. This leads to dephasing in case both tissues are present within a voxel. The SW imaging sequence itself is a flow-compensated, high-spatial-resolution conventional T2*-weighted sequence'',[2] ''phase mask is created from the MR phase images, and multiplying this with the magnitude images increases the conspicuity of the smaller veins and other sources of susceptibility effects''.[3] ''There are numerous neurologic disorders that can benefit dramatically from this sensitive method. Such diseases and conditions include, but are not limited to stroke, trauma, vascular malformations, tumors, aging and multiple sclerosis'' (MS).[1]

2. Methods

Thirty patients with known or suspected brain lesions were subjected to MRI examination using 1.5 T closed-configuration GE Signa HDxT and Avanto Siemens, according to the following parameters:

T1: TR of 550 ms, a TE of 15 ms, a 256×256 acquisition matrix, a field of view of 180 mm, a slice thickness of 3 mm and a gap of 0.3 mm, given an acquisition time of 3 min 23 s. *T2:* A repetition time (TR) of 3000 ms, an echo time (TE) of 120 ms, a slice thickness of 3 mm, a gap of 0.3 mm, 256×256 acquisition matrix, FOV = 180 mm given an acquisition

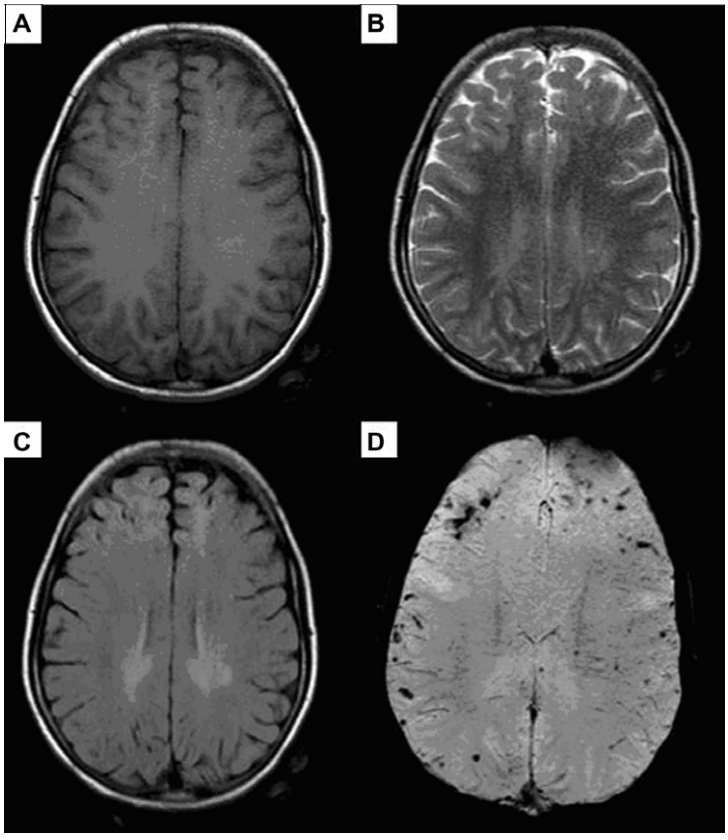

Figure 1 Thirty year old female patient in coma following road traffic accident. Conventional T1 (A), T2 (B) and FLAIR (C) images are unremarkable, while SWI minIP (D) images nicely demonstrate foci of hemorrhage at the gray white matter junctions consistent with diffuse axonal injury.

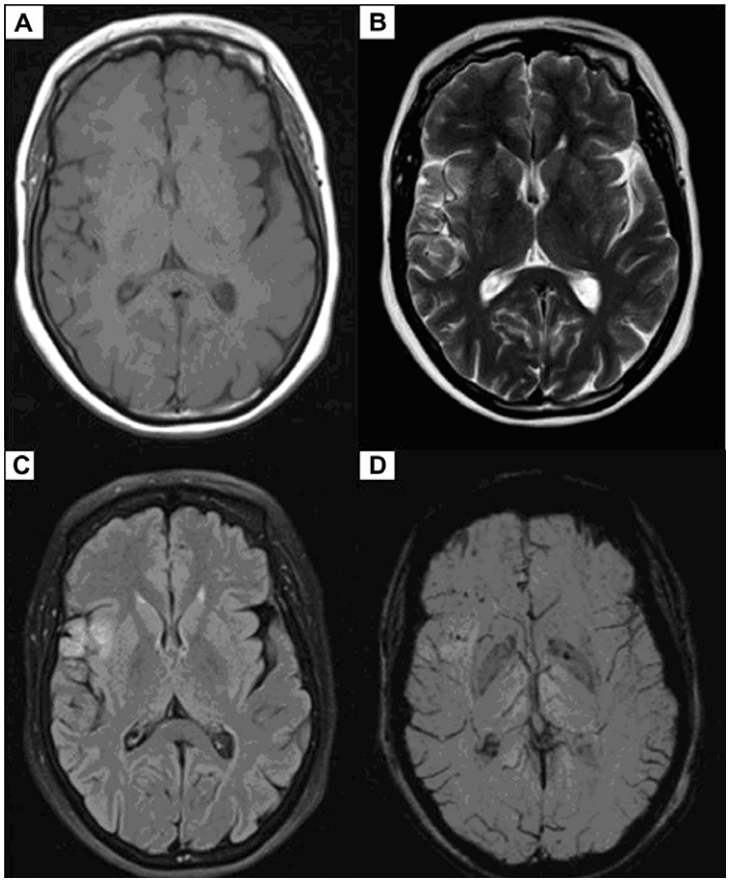

Figure 2 Sixty-three year old female patient presenting with left lag. Conventional T1 (A), FLAIR (B) and DWI (C) revealed infarct involving the right insular cortex. SWI minIP (D) images reveal foci of hemorrhagic transformation within the infarct.

time of 2 min 51 s. *FLAIR:* TR of 8000 ms, a TE of 138 ms, TI 2000 ms a field of view of 180 mm, a slice thickness of 3 mm and a gap of 0.3 mm. *SWI:* TR of 6400 ms, a TE of 30 ms, a 256×256 acquisition matrix, a field of view of 280 mm, a slice thickness of 2.4 mm and a gap of 0.2 mm, given an acquisition time of 3 min, with minIP reconstruction for the images.

3. Results

Thirty patients, compromising 20 males and 10 females, ranging in age from 3 to 79 years with a mean age of 48 years were included in the current study (Table 1). All patients with clinical findings suggestive of brain lesions had conventional MRI study as well as SWI sequence. For better demonstration of results; the patients are categorized into six groups (Table 2).

Several patients with head trauma presented to MRI with neurological signs and symptoms suggestive of brain insult, still with unremarkable CT scans, some patients showed no abnormality on MRI either, however, three patients showed positive finding only on SWI with unremarkable conventional series. The findings were multiple small scattered hemorrhagic foci matching with diffuse axonal injuries (Fig. 1).

Patients with symptoms and signs suggestive of cerebrovascular stroke presented for MRI for several reasons including questionable early hemorrhagic transformation of infarct. In three patients SWI revealed hemorrhagic transformation in ischemic infarcts not seen in conventional MRI series or initial CT scan (Fig. 2). In two patients SWI confirmed hemorrhagic transformation suspected on T1 series and/or CT scan. One patient of cerebellar infarction SWI revealed thrombosed vertebral artery.

We encountered six patients where SWI revealed multiple cerebral microbleeds, five of them were hypertensive patients presenting to the MRI unit with different complaints including headache, stroke symptoms and signs, sometimes disturbed sensorium. In those patients the microbleeds were found in central (basal ganglia and thalami) and peripheral (cerebral hemispheres) locations as well as infratentorial locations. The radiological diagnosis in those patients was chronic hypertensive encephalopathy with multiple microbleeds (Fig. 3). In four patients, all the lesions were noted only in SWI while conventional MRI imaging and initial CT scans were either unremarkable or showed involutional brain changes and/or few lacunar infarcts (see Table 3). In one patient T1 images revealed a temporal hematoma, still the associated microbleeds were only seen in SWI. In one patient presenting with dementia, multiple bleeds were identified only on SWI with a predominantly peripheral location and the radiological diagnosis was cerebral amyloid angiopathy (Fig. 4).

Multiple brain tumor patients present to the MRI department for various reasons either for diagnosing suspected tumor (primary or metastatic), evaluating and grading known tumor or for follow up after treatment. We selected six patients where

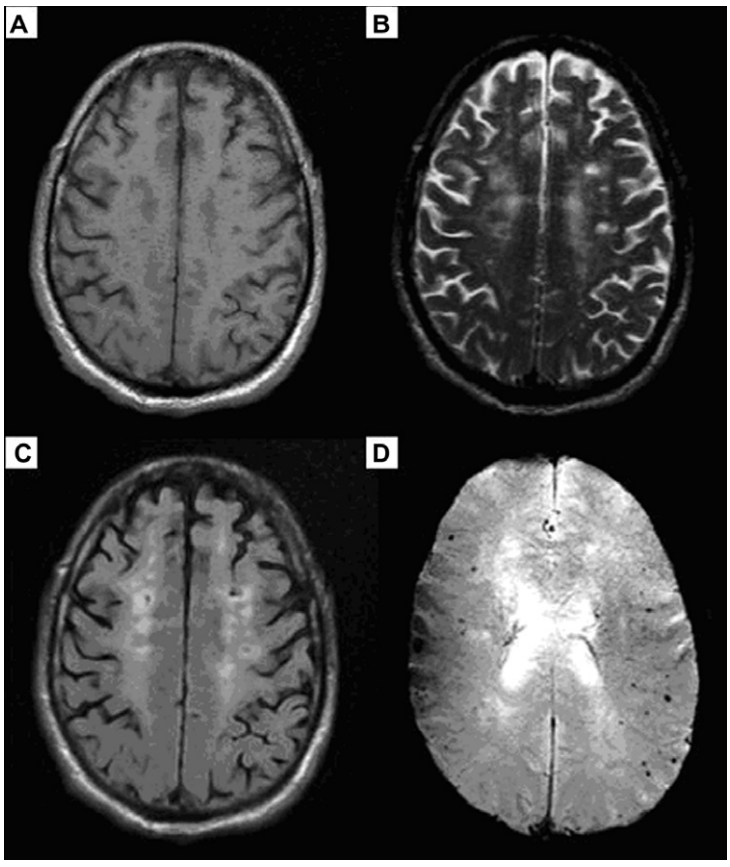

Figure 3 Sixty year old hypertensive male patient presenting with right hemiparesis. While T1 (A), T2 (B) and FLAIR (C) show only lacunar infarcts, SWI (D) reveals foci of hemorrhage in both parietal and frontal lobes matching with chronic hypertensive encephalopathy.

Table 3 Frequency of lesion detection in SWI and CT/conventional MRI among the studied patients.

Categories	SWI		CT/conventional MRI		Number
	Yes	No	Yes	No	
Category I	3	0	0	3	3
Category II	6	0	3	3	6
Category III	6	0	0	6	6
Category IV	6	0	4	2	6
Category V	5	0	1	4	5
Category VI	4	0	3	1	4
Total	30	0	11	19	30

SWI proved to be beneficial adding important information that aids in diagnosis, grading and management of those patients. In one patient with left CPA angle mass lesion, SWI revealed multiple hemorrhagic foci within the mass favoring the diagnosis of schwanomma rather than meningiomas especially that CT revealed no calcifications (Fig. 5). In another patient with left CPA lesion, on conventional imaging it was not certain whether the mass was intra or extra-axial, while on SWI a displaced vessel is clearly seen between the mass and the cerebellum revealing the extra-axial origin of the tumor (Fig. 6). One patient showing a sizable glioma, SWI confirmed and revealed the more extensive hemorrhagic transformation within the mass as well as high internal vascularity denoting high grade of the glioma (Fig. 7). In the remaining three patients with brain metastasis SWI proved to be extremely helpful where it revealed hemorrhagic nature of metastatic lesions and sometimes detecting metastatic deposits not seen on conventional imaging or even after contrast administration (Fig. 8).

In our study we encountered five patients with venous malformations and venous disease, whether incidentally discovered as in venous angioma patients, or in patients undergoing MRI for neurological symptoms as in cavernoma and sinus thrombosis patients. In two patients venous angiomas were seen, one of them was only seen on SWI images, while in the other patient SWI revealed the nature of the venous angioma which was seen only as a subtle faint linear structure on conventional series (Fig. 9). In two patients, SWI confirmed the diagnosis of bleeding cavernoma by demonstrating hemorrhagic elements, and in one of them SWI revealed another smaller cavernoma not seen on conventional scans (Fig. 10). In one patient, SWI showed thrombosed left transverse sinus which was not evident on conventional scans, the finding was confirmed by complementary MRV series.

In the last group four patients with extra-axial collections were included where SWI proved to be helpful in establishing correct diagnosis and subsequent further management of those patients. In two patients, SWI confirmed the presence of minimal intraventricular hemorrhage and in one of them the hemorrhage was seen only on SWI (Fig. 11). In one pa-

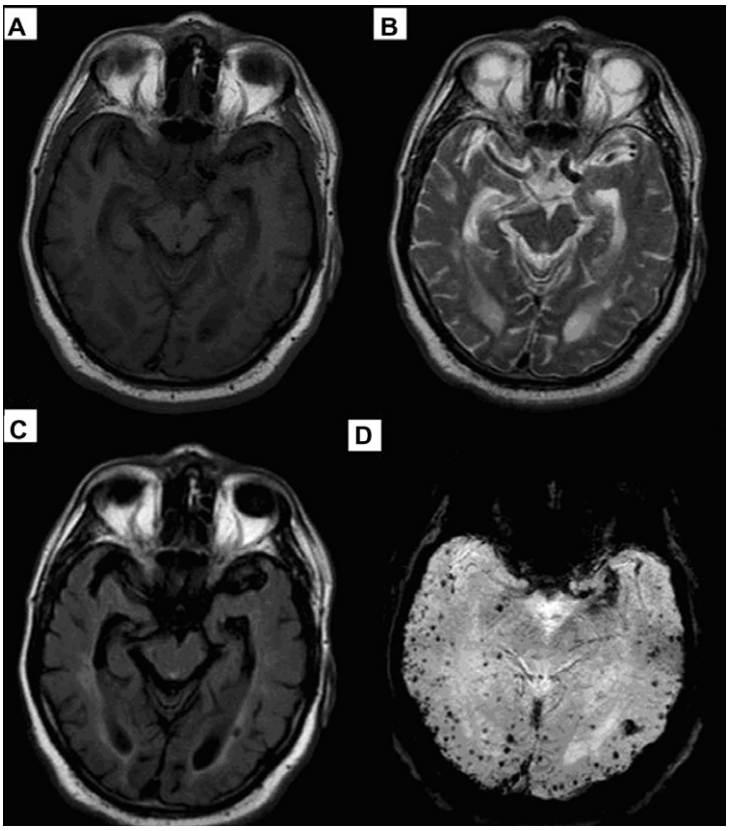

Figure 4 Fifty-nine year old male patient with dementia presenting with disturbed sensorium. T1 (A), T2 (B) and FLAIR (C) images show involutional brain changes, SWI minIP(D) images reveal multiple foci of chronic microbleeds peripherally located within both cerebral hemispheres. Establishing the radiological diagnosis of cerebral amyloid angiopathy.

tient, SWI helped confirming the diagnosis of subarachnoid hemorrhage suggested by FLAIR. In the last patient SWI helped diagnosing subdural collection of high protein content and differentiating it from subdural hematoma in the form of the absence of blooming.

4. Discussion

''Susceptibility-weighted imaging (SWI) is a novel magnetic resonance (MR) technique that exploits the magnetic susceptibility differences of various tissues, such as blood, iron and calcification''.[4]

''The detection of intracranial hemorrhage is important in the treatment and management of patients with traumatic brain injury. The identification of small hemorrhages and their locations serves as useful information regarding the mechanism of injury and the potential clinical outcome''.[5] In the current study three patients of trauma were included. These patients showed unremarkable CT scan despite the presence of neurological signs suggestive of brain insult. Conventional MRI series were also unremarkable in the three patients. SWI with its unique capability of detecting hemorrhagic elements revealed positive findings in the three patients as it shows multiple small hemorrhagic lesions along the gray white matter junctions, in the basal ganglia and the brain stem establishing the diagnosis of diffuse axonal injury. These findings match with those of Tong et al.[5] who stated that there is an improved sensitivity of SW MR imaging for detection of small hemorrhages that previously could not be visualized.

''Hemorrhagic transformation of stroke can be a devastating complication especially if the patient is considered for revascularization therapies. The mechanism of cerebral bleeding remains a remarkably complex and dynamic process involving a combination of microvascular injury with altered permeability and reperfusion integrated over time''.[6] The extravasated hemoglobin gets converted into deoxyhemoglobin, which being a paramagnetic substance causes local magnetic field inhomogeneity resulting in dephasing of protons. ''SWI, which is exquisitely sensitive to magnetic field inhomogeneity, can detect very small bleeds within the infarct''.[7] ''Also the demonstration of arterial clot with an accurate determination of its location helps to direct thrombolytic treatment, fresh clots contain a high concentration of deoxyhemoglobin and appear hypointense on SWI''.[8] In this study we included six patients presenting with clinical findings suggestive of cerebrovascular stroke where SWI proved to be very helpful in the diagnosis and management. In three patients SWI revealed tiny foci of early hemorrhagic transformation within ischemic infarcts influencing the subsequent treatment decisions. These hemorrhagic foci were not visualized either in the initial CT or in conventional MRI series. In two patients SWI confirmed hemorrhagic transformation of ischemic strokes suggested by non-contrast enhanced T1 weighted

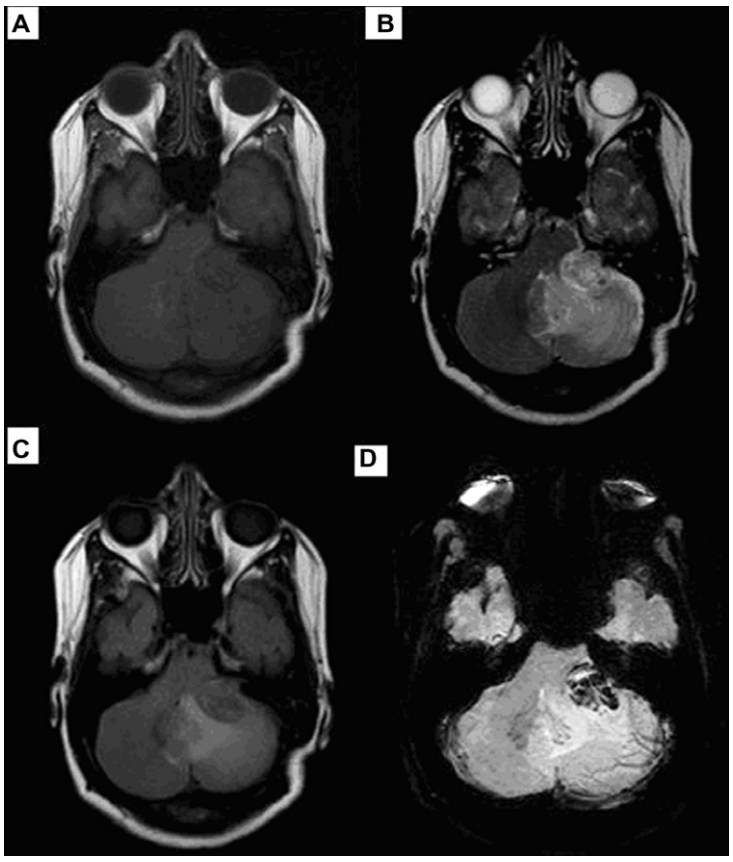

Figure 5 Thirty-eight year female patient presenting with bulbar symptoms. T1 (A), T2 (B) and FLAIR (C) images show left CPA angle lesion, SWI minIP (D) images clearly reveal hemorrhagic foci within the mass aiding in the diagnosis of schwanomma.

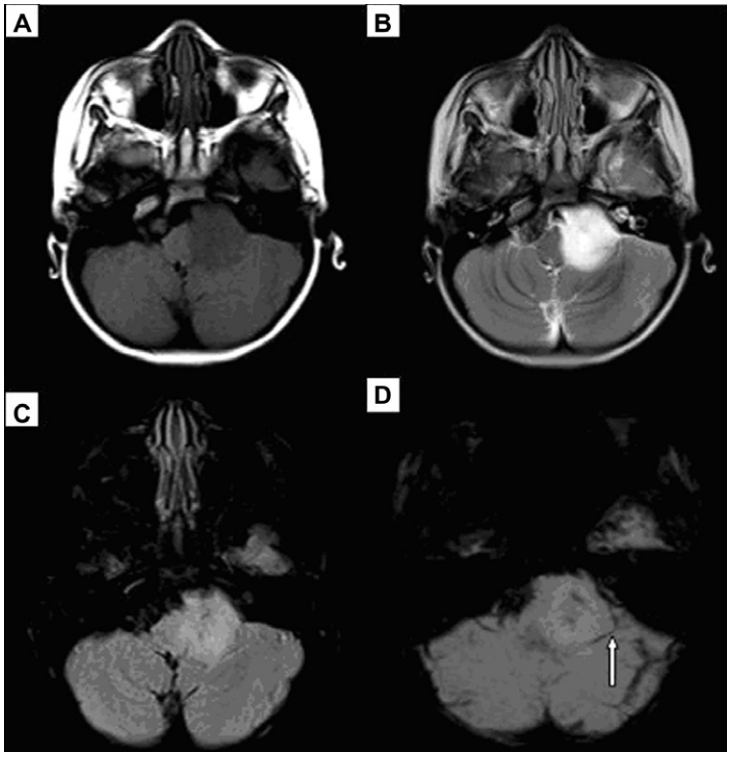

Figure 6 Three year old female patient presenting with bulbar symptoms. T1 (A), T2 (B) and FLAIR (C) images show left CPA angle lesion, SWI minIP (D) images reveals its extra-axial location by demonstrating a displaced vessel (arrow) between the mass and the cerebellum.

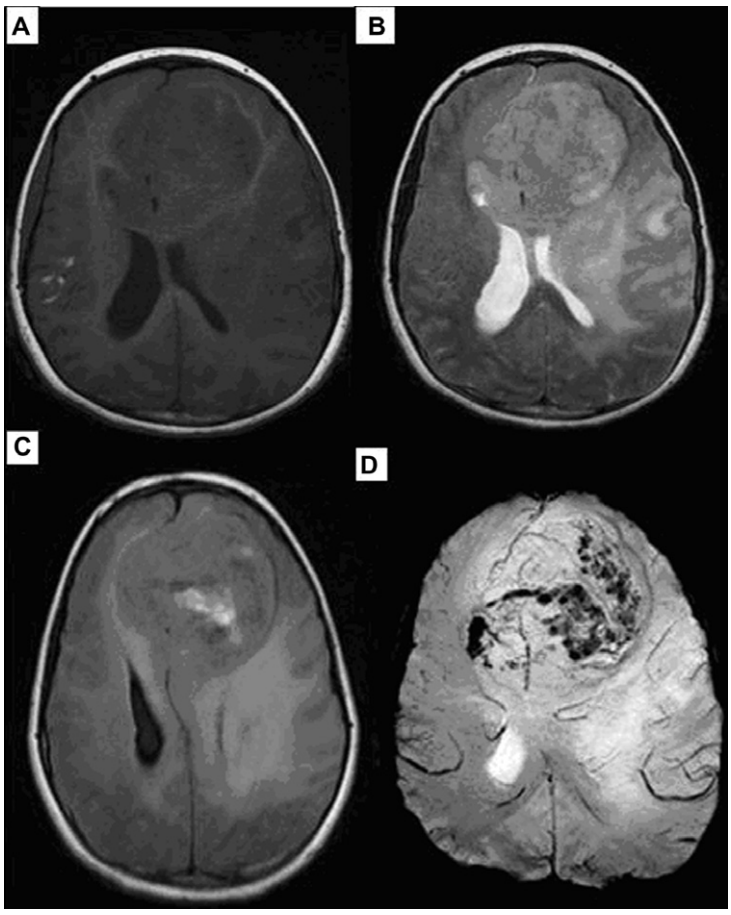

Figure 7 Twelve year old male patient presenting with disturbed sensorium. T1 (A), T2 (B) and FLAIR (C) images show sizable glioma with suspected hemorrhagic foci on T1, SWI (D) confirm and reveal the more extensive hemorrhagic elements as well as high internal vascularity denoting high grade glioma.

sequence and/or initial CT scan. While in one patient with left cerebellar hemisphere infarct SWI revealed thrombosed left vertebral artery in the form of bloomed hypointense signal which was confirmed by CTA. Based on these findings we agree with Wycliffe et al. [9] and Santhosh et al.[7] in that SWI is useful in the evaluation of acute and chronic stroke patients being extremely sensitive to even traces of hemorrhage and has potential diagnostic, as well as therapeutic, implications in acute stroke patients. It can also provide valuable diagnostic input in various stroke-related conditions and stroke mimics, and this technique should be included in the routine evaluation of stroke patients where it is essential to rule out the presence of hemorrhage within the infarct with a high degree of accuracy as thrombolysis in such patients can be catastrophic. ''The likelihood of early cerebral bleeds after ischemic stroke might be increased in patients who had the most vulnerable microvascular system''.[10] MRI demonstration of microbleeds could gain even more clinical significance if this finding could be used to identify patients at increased risk of early cerebral bleeds. ''Old microbleeds provide further evidence of severe microangiopathy with a subsequent increased vascular vulnerability''.[6] In this study SWI proved to be very helpful in detecting cerebral microbleeds not seen in CT or conventional MRI scans. In chronic hypertensive encephalopathy patients (five in number) SWI alone showed multiple microbleeds scattered in central, peripheral and infratentorial locations of the brain, and in one patient presenting with dementia SWI nicely revealed multiple peripherally located bleeds predominantly in cortical-subcortical location establishing the radiological diagnosis of cerebral amyloid angiopathy, this is in agreement with Thomas et al.[4], Santhosh et al.[7] and Mittal et al.[8] studies that SWI with its higher sensitivity identifies numerous microbleeds unidentified on routine images. This study is in agreement with Mittal et al.[8] study that SWI is a sensitive diagnostic tool which may permit more precise assessment of the natural history of cerebral amyloid angiopathy and response to therapy. The findings are also in match with Greenberg et al.[11] statement that cerebral amyloid angiopathy typically results in microhemorrhages in and around the arteriole vessel wall. Lobar microbleeds are related to cerebral amyloid angiopathy (usually involving the cortex and subcortical white matter within the frontal and parietal lobes), whereas microhemorrhages in a deep or infratentorial location typically result from hypertensive or atherosclerotic microangiopathy.

Six patients suffering primary and secondary brain tumors with useful SWI data were included in our study. In one patient with CPA lesion SWI was very helpful in demonstrating hemorrhagic foci not seen with conventional series favoring

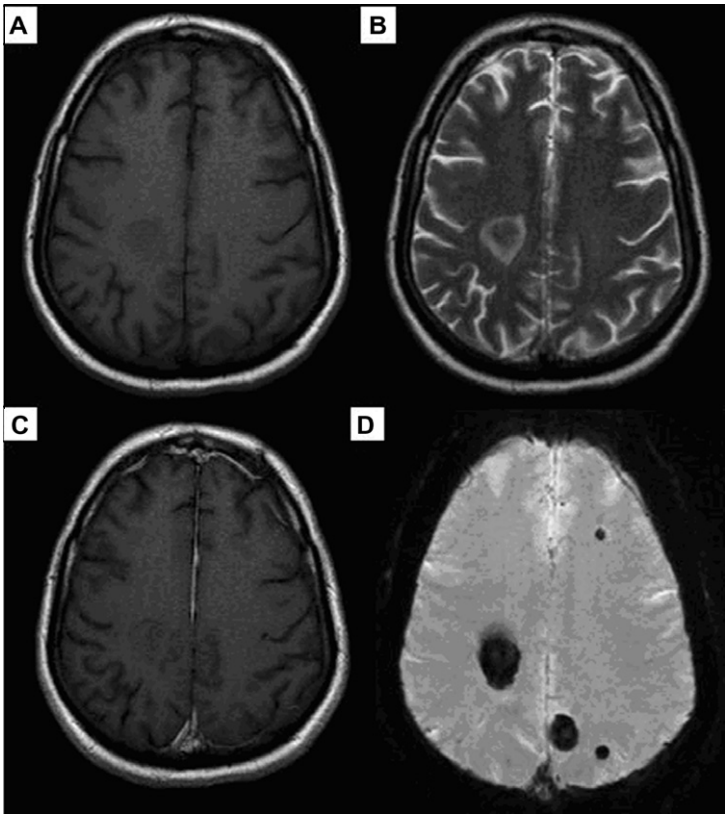

Figure 8 Seventy-two year old male patient with cancer lung. T1 (A), T2 (B) images show a subtle right parietal metastatic lesion, T1 + C (C) shows no significant enhancement. SWI (D) shows its hemorrhagic nature and reveals other multiple foci of hemorrhagic metastasis.

the diagnosis of schwanomma, in this finding we agree with Thomas et al.[4] and Mittal et al.[8] who reported that SWI can also be used to differentiate acoustic schwanommas from cerebellopontine angle meningiomas with the improved detection of microhemorrhages within schwanommas, which are not observed in the meningiomas provided that calcification is excluded by CT. In another patient with CPA tumor with questionable origin, SWI solved the problem by confirming the extra-axial nature of the mass by demonstrating a displaced vessel between the mass and the cerebellum. This is in agreement with Thomas et al.[4] and Mittal et al.[8] who found that Susceptibility-weighted imaging can also differentiate intraaxial tumors from extra-axial tumors by demonstrating the shift of vessels around the mass. One patient with sizable glioma showed marked hemorrhagic elements on SWI together with increased internal vasculature. This was in agreement with Li et al.[12] who stated that SWI sequence displayed small vessels and micro-hemorrhage which indirectly correlated with angioproliferation of the astrocytomas. Thus SWI sequence is useful for showing the characteristics of brain astrocytomas, and it is valuable in grading the tumors. This novel technique may be a promising tool for the non-invasive differentiation of low grade and high grade brain tumors. Regarding metastasis, we included three patients where SWI revealed the hemorrhagic nature of the lesions and in one patient SWI showed multiple other metastatic lesions that were not apparent in conventional series or even after contrast administration.

Under the entity of venous malformations and venous disease we included five patients. In two patients SWI proved to be helpful in detecting and confirming venous angioma, not seen on conventional scans in one patient, and seen but not reliably diagnosed in the other patient. This was in agreement with Mittal et al.[8] that SWI allows better visualization of DVAs without requiring contrast media. In two patients with cavernomas, SWI confirmed the diagnosis in both patients and in one of them SWI revealed additional smaller cavernoma diagnosing familial form. This was in agreement with Tsui et al.[13] who stated that because of the possibility of blood stagnation phenomenon and chronic microhemorrhages, cavernomas contain deoxy-Hb or hemosiderin and become very dark and, therefore, are easily detected on SWI, especially the tiny lesions. Also agreeing with Tong et al.[5] who found that SWI depicts more small cavernomas when compared with other conventional sequences. Also, because of its high degree of sensitivity, SWI can help confirm the diagnosis of cavernoma in patients presenting with cerebral hemorrhage. In the last patient of the venous disorders group, SWI showed left transverse sinus thrombosis, a finding that was not seen on conventional scans except for a retrogradely noticed faint hyperintense signal in FALIR images. Sinus thrombosis was confirmed by complementary MRV, this is in agreement with Thomas et al.[4] who found that susceptibility-weighted imaging with both phase and magnitude information facilitates the detection of venous sinus thrombo-

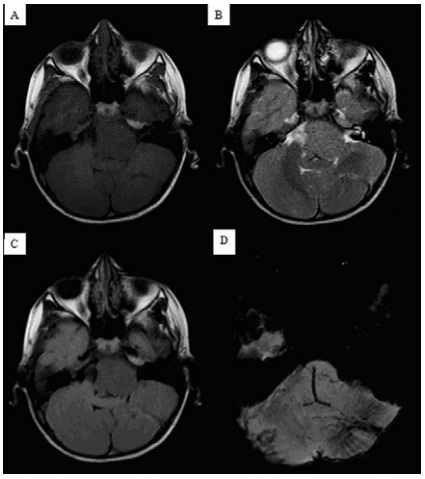

Figure 9 Seven year old male patient investigated for left CPA mass. Apart from the left CPA mass lesion. T1 (A), T2 (B) and FLAIR (C) images incidentally show an ill-defined linear structure in the left cerebellar hemisphere, SWI minIP (D) images clearly demonstrate the venous angioma (arrow) in the left cerebellar hemisphere with its characteristic medusa head appearance.

sis which is otherwise difficult to detect in conventional spin-echo T2 images.

Mittal et al.[8] stated that SWI is not only sensitive in detecting hemorrhages occurring in the brain parenchyma but, in some patients, also shows intraventricular hemorrhage and subarachnoid hemorrhage, sometimes even better than CT. In this study SWI proved to be helpful in revealing and confirming the presence of intraventricular hemorrhage, where in two patients SWI confirmed the presence of intraventricular hemorrhage and in one of them the hemorrhage was seen only on SWI. While in one patient SWI helped confirming the diagnosis of subarachnoid hemorrhage suggested by FLAIR. However, Mittal et al.[8] stated that further studies comparing subarachnoid hemorrhages in CT and SWI are needed to gain more experience. Lastly we met a patient with bilateral subdual collection where SWI helped diagnosing subdural collection with high protein content and differentiating it form subdural hematoma by the lack of blooming. This directed the diagnosis toward chronic intracranial hypotension.

5. Conclusion

Susceptibility weighted imaging should be included as a routine sequence when examining any brain pathology as it has an important role in diagnosing different brain lesions and in avoiding missing hemorrhagic lesions that may lead to catastrophic events with inappropriate therapeutic regimens.

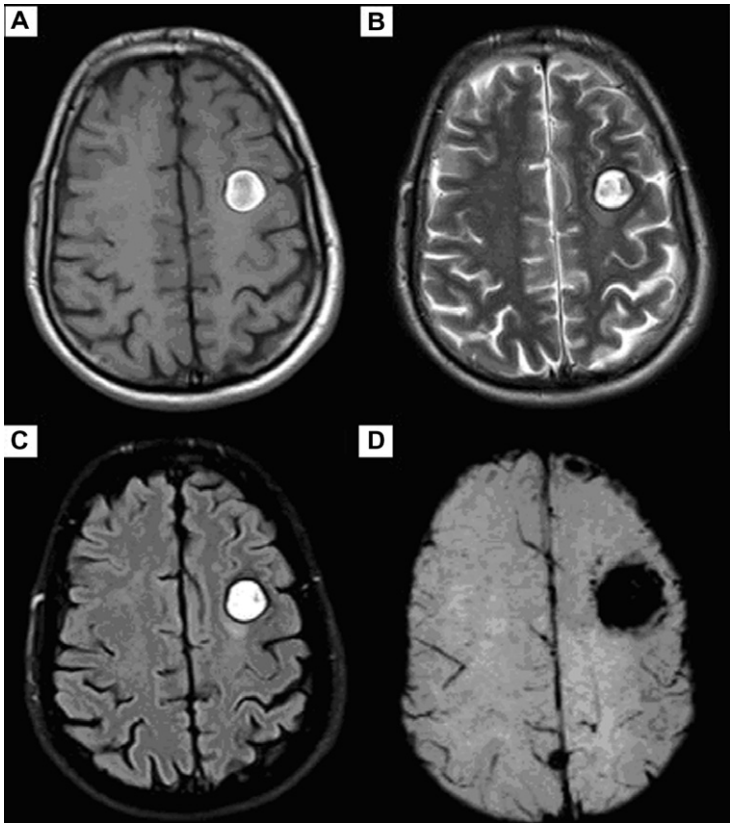

Figure 10 Fifty-five year old male patient presenting with altered sensorium. T1 (A), T2 (B) and FLAIR (C) show hyperintense left cerebral cavernoma with T2 hypointense hemosiderin ring seen within the left frontal lobe, SWI (D) confirms diagnosis and reveals another one in the right occipital lobe.

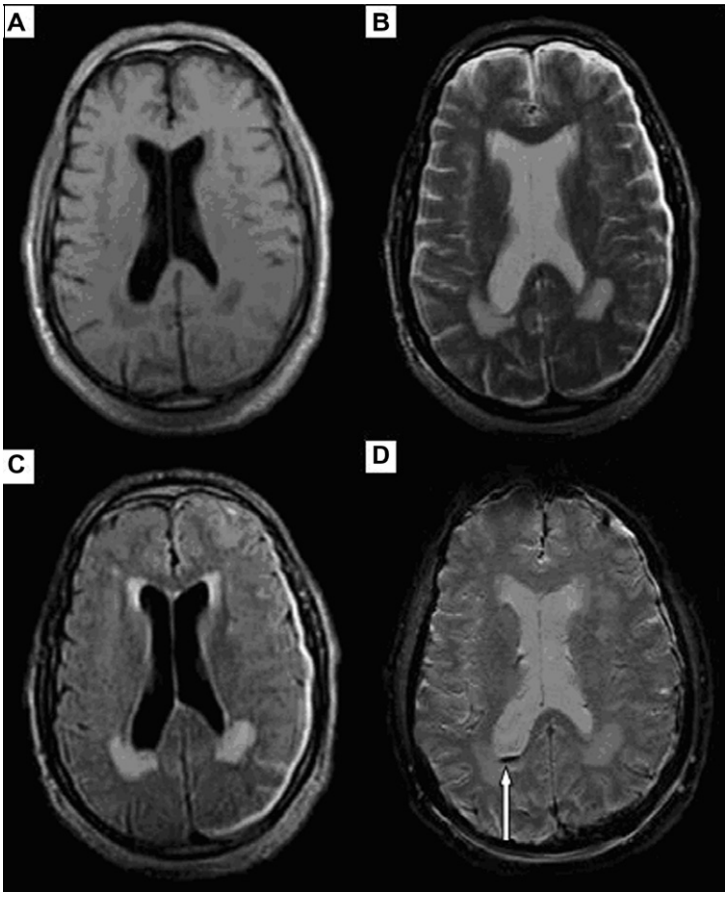

Figure 11 Seventy-three year old hypertensive male patient presenting with altered sensorium. T1 (A), T2 (B) and FLAIR (C) images reveal age matched involutional brain changes in the form of ectatic ventricles, SWI (D) revealed right intraventricular minimal hemorrhage (arrow).

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