

Susceptibility Weighted MR Imaging at 3T in Patients with Occlusion of Middle Cerebral Artery : Comparison with Diffusion Weighted Imaging Score (ASPECTS)

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Purpose : To describe the imaging findings at susceptibility weighted imaging (SWI) at 3T in patients with occlusion of middle cerebral artery, and to correlate the absence or presence of arterial bright foci in sylvian fissure, as one of their finding at SWI, with the diffusion weighted imaging (DWI) scores.

Materials and Methods : We included 12 patients with symptomatic unilateral occlusion of middle cerebral artery. Retrospective review of SWI and DWI was done. On DWI, size of infarction was analyzed according to the ASPECTS grading system. On SWI, presence of hemorrhage, dark blooming of intravascular clot, distension of medullary or cortical vein, and absence or presence of bright arterial foci in sylvian fissure were evaluated.

Results : Of 12 patients with symptomatic unilateral MCA occlusion, SWI showed dark blooming of intravascular clot in 8 patients (66.7%), distended medullary or cortical vein in 7 patients (58.3%), nonvisualization of arterial bright signal intensity in sylvian fissure in 7 patients (58.3%), and hemorrhage in one patient (8.3%). In comparison with DWI, patients with sylvian arterial bright signal intensity showed better ASPECTS score (6.4 ± 4.1) than patients without arterial bright signal intensity (4.4 ± 1.1), yet it was not statistically significant ($p=0.267$, t-test).

Conclusion : SWI at 3T provides added diagnostic information including site of occlusion, collateral flow by arterial bright signal intensity in sylvian fissure and early hemorrhagic transformation in patients with symptomatic MCA occlusion.

Index words : Susceptibility weighted imaging
Diffusion weighted imaging
Middle cerebral artery occlusion
Stroke

Introduction

Stroke can be defined as an acute central nervous

system injury with an abrupt onset. Acute ischemia constitutes most part of stroke and is a major cause of mortality and morbidity. Large vessel occlusions, such as internal carotid artery (ICA), middle cerebral artery

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(MCA) and posterior cerebral artery (PCA), constitute approximately 50% of all acute cerebral infarction. Among the rest, MCA is a leading portion of cerebral vessel occlusion (1, 2).

Early diagnosis is the goals of an imaging evaluation for acute stroke. Another goal of an imaging evaluation is to obtain accurate information about the intracranial vasculature and brain perfusion for guidance in selecting the appropriate therapy. A full evaluation may be done with a combination of computed tomography (CT) or magnetic resonance (MR) imaging techniques. The introduction of new MRI techniques has touched up acute stroke diagnosis. Diffusion- and perfusion-weighted sequences and magnetic resonance angiography (MRA) provide data on the pathophysiology of ischemia and may contribute to therapeutic decisions.

Susceptibility-weighted imaging (SWI) also adds informations about acute stroke. Susceptibility weighted imaging (SWI) is a magnetic resonance (MR) technique, which is sensitive to paramagnetic substances, such as deoxygenated blood, blood products, iron, and calcium (3). This technique has been described in variety of neurological disorders, such as trauma, tumors, vascular malformations, multiple sclerosis, venous thrombosis, and stroke (4). SWI can be a useful MR sequence in the work-up of stroke patients, the characteristic imaging findings often may be seen only in this sequence, such as detection of intracranial hemorrhage, hemorrhagic transformation of acute stroke and detection of intraarterial thrombus. SWI at higher field strength has benefits of increased sensitivity to altered susceptibility (4), but there is limited number of reports regarding the description of SWI findings in patients with acute stroke. The purpose of this study is to describe the SWI findings in patients with the occlusion of middle cerebral artery, and to correlate them with diffusion weighted imaging findings.

Materials and Methods

The study was institutional review board approved, and a waiver of consent was obtained for a Health Insurance Portability and Accountability Act-compliant retrospective study. Twelve patients (3 men, 9 women; age range 44–90; mean age 71) who experienced MCA

territory stroke symptoms and had occlusion of the unilateral MCA on MR angiography (MRA) and infarction in the MCA territory on DWI were included in this study. Nonvisualization of entire M1 segment of the MCA on MRA was considered as arterial occlusion, and patients with partial segment loss of arterial flow signal was excluded due to the possibility of severe stenosis without occlusion. The mean duration between symptom onset and acquisition of SWI and DWI was 7.9 hours (range 0.5–36).

SWI and DWI were obtained with 3T MR unit (Verio, Siemens Medical Solutions, Erlangen, Germany). SWI acquisition was performed with a T2* weighted gradient echo sequence with FA = 15°, TR/TE = 28/20 ms, matrix number = 256 × 182, FOV = 21 cm × 21 cm, slice thickness = 2 mm. SWI and minimum intensity projection (mIP) images were acquired by in-line postprocessing of magnitude and phase images, and these post-processed mages were used for the evaluation of the imaging findings in this study. DWI was performed with single-shot echo-planar imaging (ss-EPI), and parameters were as follows; b-value 1000 s/mm², TR/TE 5800/99 ms, slice thickness 4 mm, FOV 23 cm × 23 cm, matrix 128 × 128, NEX 1.

Two experienced neuroradiologists (each with over 10 years experience) interpreted the SWI and DWI. Four imaging findings were evaluated on SWI ; 1) arterial blooming at the thrombosed segment of occluded MCA, 2) presence or absence of bright arterial signal intensity in sylvian fissure, 3) prominence of medullary or cortical vein at the MCA territory compared to the opposite side, and 4) presence of

Table 1. Characteristics of 12 Patients with MCA Occlusion

Case	Sex/Age	Duration	Occlusion Site
1	M/64	0.5 hours	MCA
2	F/65	0.5 hours	MCA + ICA
3	M/63	0.8 hours	MCA
4	F/90	1.5 hours	MCA + ICA
5	F/62	4 hours	MCA + ICA
6	F/69	4 hours	MCA
7	F/79	4.5 hours	MCA
8	F/78	8 hours	MCA + ICA
9	M/88	9 hours	MCA + ICA
10	F/83	12 hours	MCA
11	F/44	14 hours	MCA
12	F/66	72 hours	MCA + ICA

parenchymal hemorrhage were studied. To evaluate infarction size on DWI, the areas of bright signal intensity on DWIs were scored according to the criteria of Alberta Stroke Program Early CT Score (ASPECTS) (5).

Results

12 consecutive patients were identified from the radiology data base who were diagnosed with MCA occlusion on CTA, MRA or DSA and underwent SWI on a 3T magnet from March to August 2009 (Table 1).

Table 2 summarizes the MR findings for SWI and DWI in the 12 patients with symptomatic unilateral MCA occlusion.

Signal loss at the occluded vessel was seen in 8 patients (66.7%), and it exceeded true MCA diameter (blooming). At the territory of occluded MCA, distended medullary vein or cortical vein was seen in 7 patients (58.3%). There was one patient (8.3%) with early hemorrhagic transformation seen as inhomogeneous dark signal intensity with mass effect.

Arterial bright signal intensity in the sylvian fissure distal to the occluded M1 segment of MCA was seen in 5 patients (41.7%). In comparison of patients with or without arterial bright signal intensity, ASPECTS score was higher in patients with arterial bright signal intensity in the sylvian fissure (mean \pm SD = 6.4 \pm 4.1) than those without arterial bright signal intensity

(mean \pm SD = 4.4 \pm 1.1), but it was not statistically significant ($p=0.267$, t-test). Two patients with infarction involving entire MCA territory (ASPECTS=0) showed total loss of arterial bright signal intensity in sylvian fissure.

Discussion

SWI is a fully velocity-compensated, three-dimensional (3D), gradient-echo (GRE) sequence that uses both phase and magnitude data to achieve intense sensitivity to tissue magnetic susceptibility effects. The phase and magnitude data are acquired. The substances which have different magnetic susceptibilities compared to adjacent tissues result in the phase differences, that is the basis of the contrast between brain versus blood, iron laden tissues and venous structures (3, 6, 7). The phase images are used to create a phase mask after unwrapping and high pass filtering, that is then multiplied with the magnitude images to enhance the conspicuity of paramagnetic substance (8).

Most frequent SWI finding in patients with symptomatic unilateral MCA occlusion, in our study, was arterial blooming of clot in occluded vessel (Fig. 1). The term of "blooming" is used for emphasis or to express annoyance. Susceptibility-based perfusion MRI demonstrates thrombosed middle cerebral artery as signal loss along the course of artery. It is called also as

Table 2. SWI Findings and NIHSS in Patients with MCA Occlusion

Case	SWI Findings				DWI (ASPECTS)
	Hemorrhage	Arterial Blooming	Loss of Bright Arterial SI	Venous Prominence	
1	No	Yes	No	No	6
2	No	Yes	Yes	Yes	9
3	No	Yes	Yes	Yes	9
4	No	Yes	Yes	No	0
5	No	No	No	Yes	7
6	No	No	No	No	6
7	No	Yes	No	Yes	5
8	No	Yes	Yes	Yes	2
9	No	Yes	Yes	Yes	3
10	Yes	No	Yes	No	0
11	No	Yes	Yes	Yes	8
12	No	No	No	No	8

Note.— Alberta Stroke Program Early CT Score (ASPECTS) was devised to quantify the extent of early ischaemic changes in the middle cerebral artery territory on CT images by using a 10-point topographic scoring system. According to this system, the MCA territory is divided into 10 regions, each of which accounts for one point in the total score. One point is deducted from that score when each area involved in stroke.

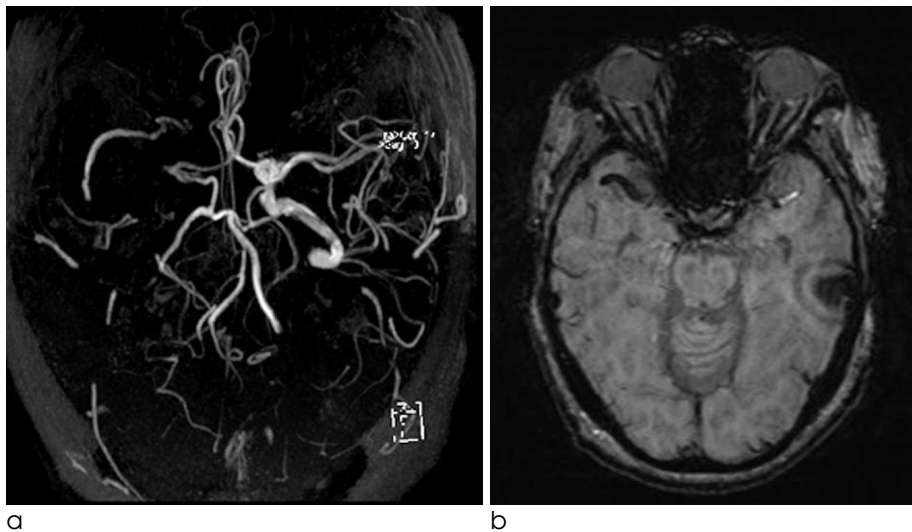


Fig. 1. Arterial blooming. 3-dimensional time-of-flight MRA (a) shows occlusion of right middle cerebral arteries. Dark signal intensity of clot in right middle cerebral artery is demonstrated on susceptibility-weighted MR image (b). The susceptibility effect, attributed to clot deoxyhemoglobin content, exceeds the true MCA diameter.

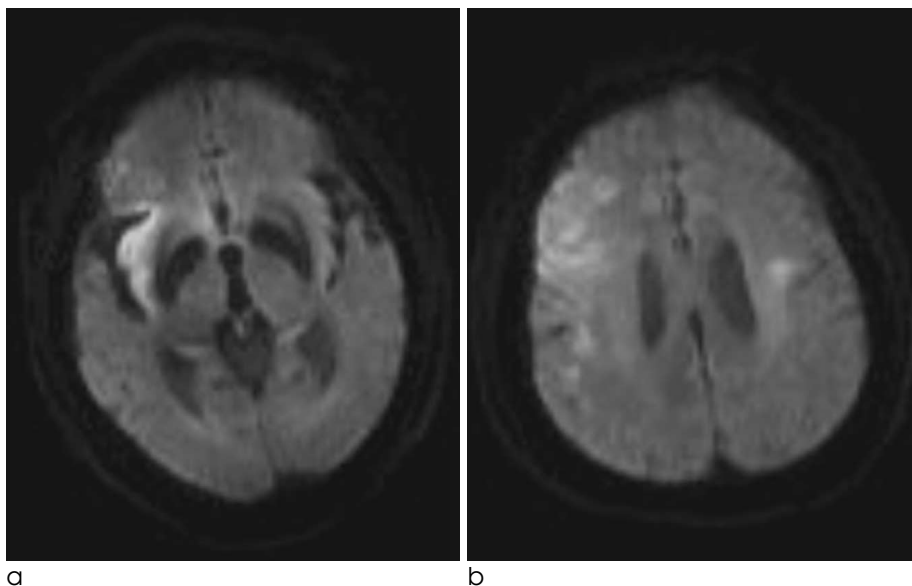
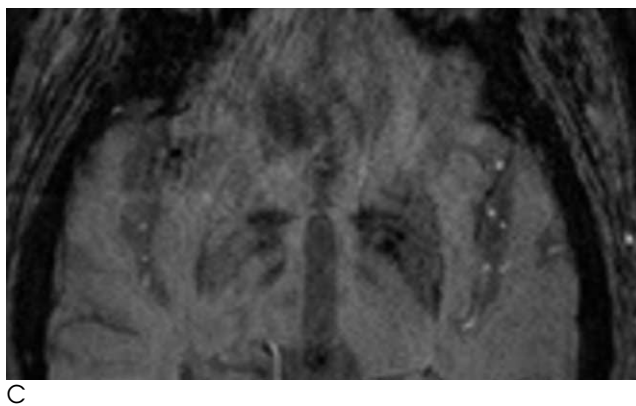


Fig. 2. Loss of arterial bright signal intensity in sylvian fissure. Diffusion-weighted MR imaging (a) shows restricted diffusion area, representing acute infarction, involving right insular region. In the slice of more upper portion (b), restricted diffusion areas are also noted in the cortical and subcortical area. On magnified image of SWI (c), loss of tiny arterial bright signal foci are demonstrated in the right sylvian fissure as compared with the left side.



MCA magnetic susceptibility sign (9). This susceptibility change is ascribed to the high deoxyhemoglobin content of fresh clots. This sign may be correlated with the

hyperdense MCA sign at nonenhancing CT. Chalela et al also briefly reported it on the hypointense MCA sign at gradient-echo (GRE) imaging (10). The susceptibility effect is also named as arterial "blooming" because the effect exceeds the true MCA diameter (11) (Fig. 1).

The outcome of tissue at risk for necrosis in stroke patient depends on the presence of an efficient collateral blood flow (12). Previously, the assessment of leptomeningeal collateral circulation in acute stroke mainly relies on the analysis of perfusion or contrast enhanced image for identification of collaterally perfused areas (13). On susceptibility-weighted MR image at 3T in our series, the leptomeningeal collateral vessels are demonstrated as bright dots in sylvian

fissure (Fig. 2). This arterial bright signal intensity is thought to be of time-of-flight effect from 3D gradient echo sequence. In our series, two patients with infarction involving entire MCA territory (ASPECTS=0) showed total loss of this arterial bright signal intensity. Furthermore, ASPECTS score was higher in patients with arterial bright signal intensity in sylvian fissure (range 5–9, median 7) than those without arterial signal intensity (range 0–8, median 3) in our series, although it was not statistically significant. This finding can represent the visualization of efficient leptomeningeal collaterals in sylvian fissure because patients exhibiting this sign had smaller infarct

volumes at baseline. Because number of patients in our study was too small to show statistical significance, further study for demonstration of correlation between collateral flow and spared arterial bright signal intensity distal to the occluded MCA on SWI should be warranted.

Deoxygenated hemoglobin is paramagnetic in SWI with a hypointense signal. Decreased arterial blood flow will also cause an increase in the amount of deoxyhemoglobin (11, 14). The oxygen extraction fraction (OEF) is defined as the ratio of deoxyhemoglobin to oxyhemoglobin in the capillaries and venous compartments. In stroke patient, the

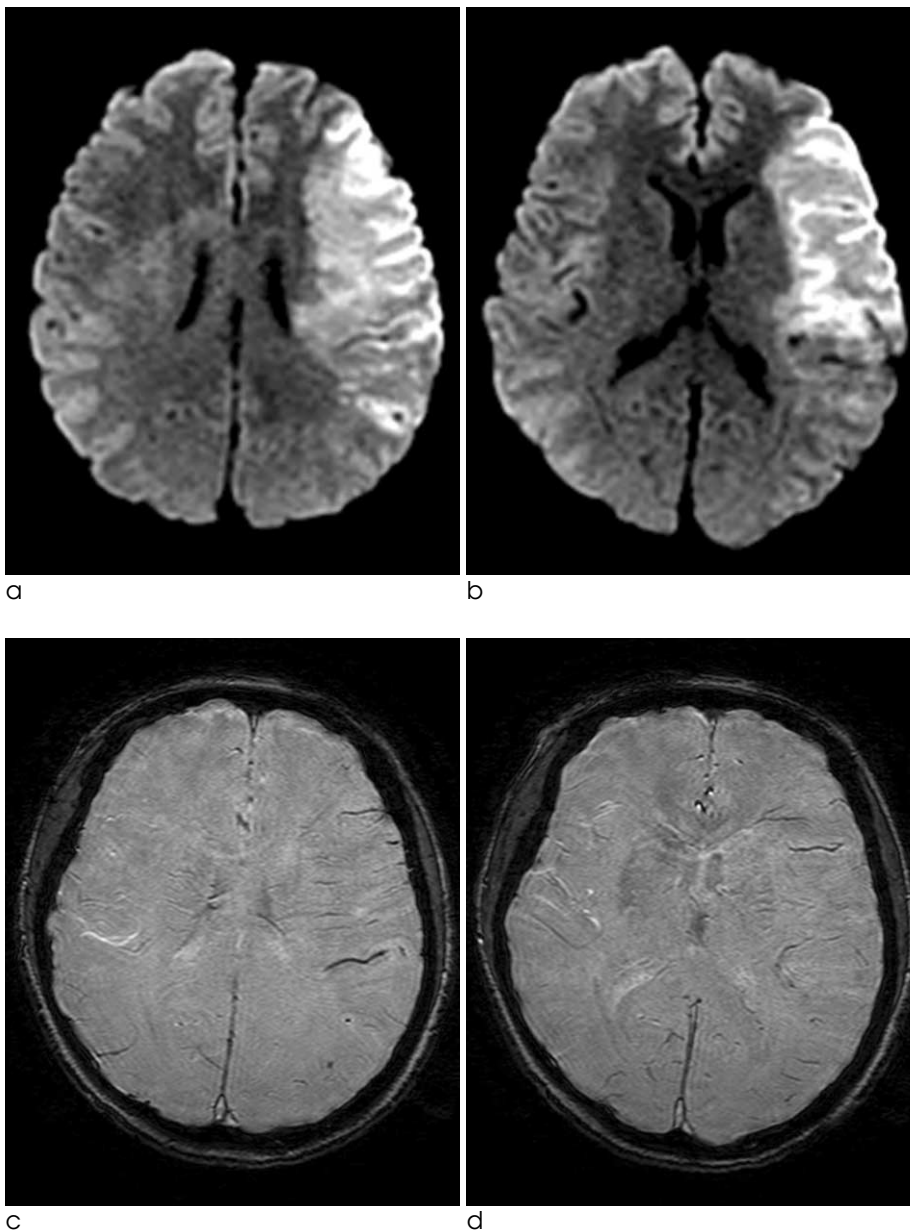


Fig. 3. Prominent veins. Diffusion weighted image (a & b) shows an acute infarct in the cortical and subcortical layer of left insula and frontoparietal lobe. On SWI (c & d), cortical veins are prominent over the corresponding area.

oxygen extraction fraction is markedly increased in the penumbra following arterial occlusion. Therefore this high OEF of the cortical veins increase the conspicuousness of draining cortical veins in the area of decreased perfusion. On susceptibility-weighted imaging, prominent asymmetrical cortical veins (Fig. 3) may represent possibility of being decreased perfusion including penumbra.

While the gold standard for detecting hemorrhage in stroke patients is considered as computed tomography (CT), the magnetic resonance imaging (MRI) is coming out as a reliable tool for the detection of bleeding. Susceptibility-weighted imaging (SWI) is extremely sensitive in detecting hemorrhage (4). Thus SWI helps to differentiate between ischemic and hemorrhagic strokes. This sequence also can contribute decision-making in revascularization therapies and assessment of cerebral hemodynamics following stroke (15).

In our cases, only one among the 12 consecutive patients shows hemorrhage associated with acute cerebral infarction although intracerebral hemorrhage/microbleeding or hemorrhagic transformation is not rare condition during acute stroke. Hemorrhagic transformation of stroke is observed in approximately 20~40% of all stroke patients within the first week of onset (16), and could be a devastating complication if the patient is considered for revascularization therapies. Conventional MRI often fails to detect microbleeding or small amount of intracerebral hemorrhage, but susceptibility weight MR sequences is more sensitive to detect the hemorrhages in the early state (10). The deoxyhemoglobin, converting from extravasated hemoglobin, is a paramagnetic substance and causes local magnetic field inhomogeneity. It is more detectable on susceptibility-weighted sequences, because SWI is exquisitely sensitive to magnetic field inhomogeneity. So small bleeds within the infarcted area can be detected on SWI MR sequence (17).

Our study contains several limitations. First, retrospective observation was done for relatively small number of case. Second, patients with acute MCA occlusion beyond 4 hours from onset are included in this study. Further study with larger number of the patients evaluated within 4 hours from onset of symptom would be needed for proper determination of clinical implication of SWI in the management of the hyperacute stroke patient.

In conclusion, susceptibility-weighted MR imaging at 3T is useful in the evaluation of acute stroke patients. In current clinical practice, this sequence provides relevant information about MCA occlusion as well as other vessel-originate acute cerebral infarction. Susceptibility-weighted technique also assists to diagnosis in various stroke-related conditions.

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중대뇌동맥폐색환자의 3T 자화율강조영상: 확산강조영상점수(ASPECTS)와의 비교

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목적: 중대뇌동맥 폐색환자의 3T 자화율강조 영상소견을 분석하고, 그 소견 중 하나인 실비안열에 동맥고신호 강도의 소실여부와 확산강조영상 점수를 비교 하고자 한다.

대상 및 방법: 편측중대뇌동맥 폐색을보인 환자 12명의 자화율 강조영상을 후향적으로 분석하고 이를 확산 강조영상과 비교하였다. 확산 강조영상은 ASPECTS 점수를 분석하였고, 자화율 강조영상은 혈종의 유무, 혈관내 혈전에 의해 번지는 검은 음영, 수질정맥 및 피질정맥의 확장, 실비안열부위에 관찰되는 동맥고신호강도의 소실여부를 평가하였다.

결과: 12예의 증상을 보인 편측 중대뇌동맥 환자의 자화율 강조영상에서 혈관내 혈전에 의한 검은 음영이 8예(66.7%)에서 보였고, 수질정맥 혹은 피질정맥의 확장이 7예(58.3%), 실비안열에 동맥고신호 강도의 소실이 7예(58.3%), 혈종변화가 1예(8.3%)에서 관찰되었다. 확산 강조영상과의 비교에서, 폐색측실비안열에 고신호의 동맥 신호강도가 남은 군은 소실을 보인군에 비하여 좋은 ASPCTS 점수를 보였으나, 이는 통계적으로 유의하지 않았다($p=0.267$, t-test).

결론: 자화율 강조영상은 증상을 보인 중대뇌동맥폐색환자에서 유용한 부가정보를 제공한다.

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