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〈特別講演〉

## The Role of MR Angiography in Neuroradiology

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### 神経放射線診断における MR 血管撮影の役割

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頭蓋内、および頸部の病変を疑われた99症例に、MR 血管撮影を time of flight 法によって実施した。撮像装置は1.5テスラー超電導型装置（シーメンス Magnetom）で、撮像 pulse 系列は、FISP、flip 角度15～25度、TR 40msec、TE 7msec、マトリックス256×256×32～64、slice 厚5～8cmで、FOV 25cmで読み取り方向と slice 方向に速度補償磁場を加えた。閉塞性疾患、血管による脳神経圧迫症候群、動静脈奇形、動脈瘤、もやもや病などの血管性病変において、本法の有用性が高かつ

た。本法には撮影野が狭いこと、渦流や複雑な流れの血流で、信号欠損が生じること、空間分解能が低いこと、撮影野の末梢や遅い血流が描出困難なことなどの欠点はあったが、spin echo 法と同時に読影を進めると、有用な情報が53.2%に得られた。MR 血管撮影は技術的進歩によって、頭蓋内および頸部の血管に関する情報を与える非侵襲的な検査法に発展し、今後、神経放射線診断に果たす役割が大きくなることが予測される。

#### I. Introduction

Magnetic resonance (MR) imaging has been used widely for imaging of various intracranial abnormalities. However, this technique has not been widely applied for the evaluation of the cerebral vasculature in spite of its high sensitivity to the blood flow. With recent developments of the MR angiographic techniques, it has become possible to study extracranial and intracranial blood flow both quantitatively and anatomically<sup>1)~6)</sup>. However, the clinical value of MR angiography in neuroradiology has not been evaluated in a wider scale.

The purpose of this study is to evaluate the value and limitations of MR angiography in the diagnosis of intracranial diseases with special attention to cerebrovascular diseases.

#### II. Principle of MR Angiography

There are basically two principles of MR angiography in obtaining signals from the flowing blood, while suppressing signals from the stationary tissue. The first is time of flight angiography<sup>1)~4)</sup> and the other is phase contrast angiography<sup>5)~8)</sup>. Furthermore, 2 DFT and 3 DFT methods are available for acquisitions of MR angiography, in which repetition time (TR), echo time (TE), flip angle, slice thickness,

slice orientation, flow compensation and presaturation all play significant roles. Time of flight angiography and phase contrast angiography can be obtained either with 3 DFT and 2 DFT acquisition techniques.

### III. Materials and Methods

The MR equipment used was a 1.5 T superconductive unit (Siemens, Magnetom). The time of flight technique was used with 3D FISP, including flip angle of 15–25 degrees, TR 40 msec/TE 7 msec and acquisition matrix of  $256 \times 256 \times 32 - 64$  with the slice thickness of 5 to 8 cm. The field of view was 25 cm, and one data acquisition was applied. The scan time was 5 minutes and 28 seconds for images of 32 partitions and 10 minutes and 56 seconds for images of 64 partitions. Presaturation techniques were applied in some cases. Gd-DTPA was used in some cases as contrast media, when the vessels of distal and slow flowing blood were imaged.

Data sets were reconstructed by means of a ray-tracing technique that incorporates a maximum-intensity projection<sup>9,10</sup>.

A total of 99 patients were studied with MR angiography. The ages of the patients varied from 6 to 83 years with the mean age of 52.6 years. Most patients underwent MR imaging of the brain because of known or suspected cerebrovascular diseases or other associated conditions and they were studied subsequently or on the same sitting with MR angiography.

The evaluation was made on 94 cases whether MR angiography provided additional, equal or less information to the routine spin echo images.

### IV. Results

#### 1. General evaluation

MR angiography gave additional information to spin echo techniques in 50 of 94 patients evaluated (53.2%) (Table), whereas 25 patients (26.6%) provided no additional information and information of MR angiography in 19 patients (20.2%) was inferior to that of spin echo technique. Useful information was obtained more frequently in steno-occlusive diseases and in facial and trigeminal nerve compression syndromes.

#### 2. Steno-occlusive disease

The site of the stenosis and occlusion was well delineated (Fig. 1). The degree of stenosis was generally more marked on MR angiograms than on conventional angiograms. In addition, arterial portion distal to the stenosis was imaged considerably smaller in caliber. Basilar and vertebral artery occlusions showed no visualization of the vessels distal to the occlusion, while the original MR images revealed high signal

Table Comparison of MR Angiography with Spin Echo Images

	SE<MRA	SE=MRA	SE>MRA	Total
Steno-occlusive disease	14	8	3	25
Facial or trigeminal compression	11	11	0	22
Brain tumor	8	3	6	17
AVM	7	1	1	9
Moyamoya disease	6	1	0	7
Aneurysm	3	1	2	6
CCF	0	0	5	5
Others	1	0	2	3
Total (%)	50 (53.2)	25 (26.6)	19 (20.2)	94 (100)

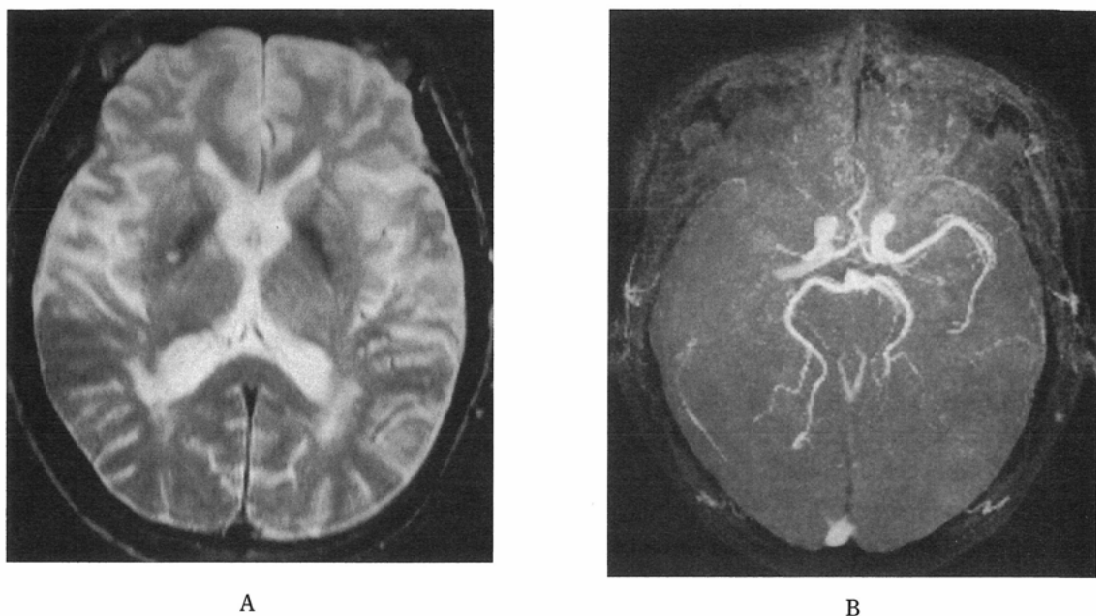


Fig. 1. Complete occlusion of the right middle cerebral artery at its horizontal portion in a 57-year-old male  
A: T1 weighted image. There are several spotty high density areas in the basal ganglia  
B: MR angiogram. There is occlusion of the horizontal portion of the right middle cerebral artery. Collateral vessels are not well shown.

intensity, making it possible to make a diagnosis of thrombotic occlusion of the basilar and vertebral artery. Only major collateral vessels were shown in a small number of cases in spite of the presence of abundant collaterals on conventional angiograms. Minor stenosis of the arteries was difficult to diagnose with certainty because of small artefactual defects.

When ischemic lesions of high signal intensities were present on spin echo images, it was possible to demonstrate a stenosis or occlusion responsible for the abnormalities.

### 3. Arteriovenous malformation

Arteriovenous malformations in 11 patients were studied with MR angiography and it was possible to demonstrate the nidus, feeding arteries and draining veins to good advantage. Findings were confirmed with intraarterial DSA or conventional angiography. The feeding arteries and the nidus of the malformations were demonstrated to good advantage in most cases, while draining veins were not demonstrated in a smaller number of cases (Fig. 2).

### 4. Aneurysm

Aneurysms were evaluated with 3 dimensional viewing from multiple angles, which was helpful in demonstrating the neck of the aneurysm in relation to the parent artery. Jet flow into the aneurysm was also demonstrated as a flow void in one case. In another case, the aneurysm at the trifurcation of the middle cerebral artery was not detected for diagnosis with the subtraction technique because the aneurysm was rephased on both rephased and dephased images and the lesion was subtracted on MR angiograms. However, the original images showed the lesion for the definitive diagnosis. In a third case dissecting aneurysm of the vertebral artery was shown as a stenotic lesion with definite dissection being demonstrated on the original images.

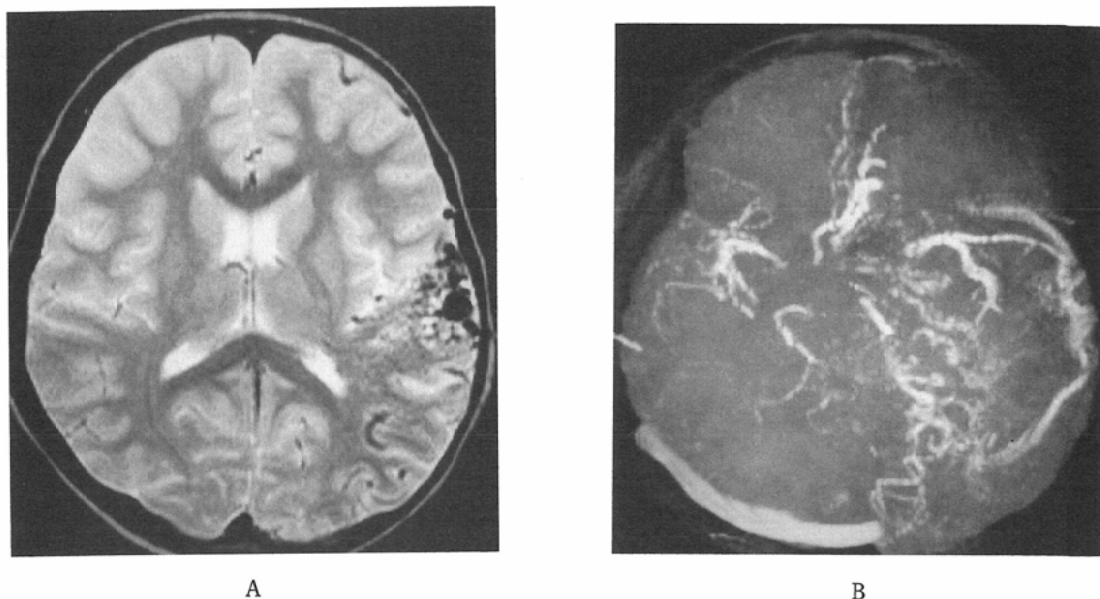


Fig. 2. Arteriovenous malformation of the left temporal lobe in a 9-year-old female.  
 A: T2 weighted image. There are linear and round flow voids in the left temporal lobe.  
 B: MR angiogram. Abnormal vascularity is demonstrated in the left temporal lobe with feeding arteries from the middle cerebral as well as posterior cerebral arteries. The draining veins drain into the superficial sylvian vein as well as toward the lateral sinus.

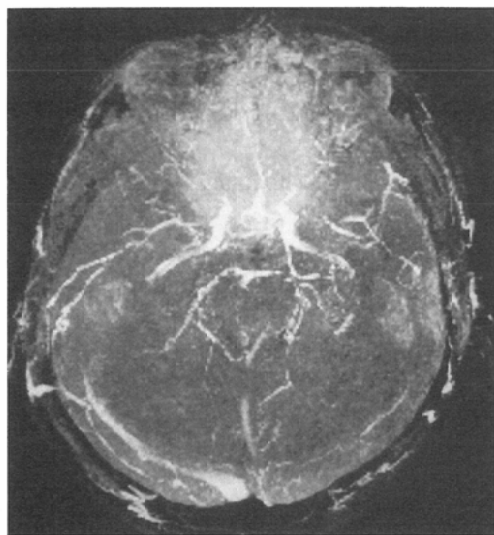


Fig. 3. Moya-moya disease in a 32-year-old male.  
 MR angiogram in axial projection. The anterior and middle cerebral arteries are occluded or considerably narrowed with reconstitution of the distal branches.

## 5. Moyamoya disease

With MR angiography, the occlusion of the supraclinoid portion of the internal carotid artery was demonstrated bilaterally with extensive collateral vessels over the surface of the brain and within the brain (Fig. 3). However, demonstration of collateral vessels was undergraded, because small collaterals were often not demonstrated. MR angiography was useful in the diagnosis or the follow-up of the patients with moyamoya disease, when initial conventional angiograms were available.

## 6. Brain tumor

Arterial and venous displacement by tumors was demonstrated well. Although feeding arteries and draining veins were demonstrated well, tumor vessels and tumor stains were not individually identified. Involvement of the dural sinuses was demonstrated in parasellar tumors. In meningiomas, the middle meningeal artery was demonstrated with spoke like radiating vessels going into the tumor. This finding was diagnostic of a meningioma. In another case with a nasopharyngeal tumor, there was narrowing of the cavernous portion of the internal carotid artery, indicating tumor encasement of the artery in the cavernous sinus.

## 7. Facial and trigeminal compression

On MR angiograms, it was possible to see small vessels adjacent to the 5th and 7th nerves, but clear demonstration of the relationship of the vessels to these nerves was difficult. When original images were viewed together, the proximity of the vessels to the cranial nerves was demonstrated to good advantage. In 75% of trigeminal neuralgia, close contact of the vessels, mainly of the superior cerebellar arteries, was demonstrated, while there was also contact of the vessels on the asymptomatic side in 41%. For the evaluation of hemifacial spasm, arterial contact to the nerve was demonstrated in 100% for the anterior or posterior inferior cerebellar arteries, while the arterial contact was shown in 29% on the asymptomatic side.

## V. Discussion

The results of this study are preliminary, but indicate that MR angiography can provide additional useful information to the conventional spin echo MR images in many clinical situations. MR angiography can increase the sensitivity and specificity of the conventional MR imaging by adding only 10 to 20 minutes to the routine imaging time<sup>4,5,7,10-13</sup>.

Although there are numerous limitations of MR angiography, stereoscopic or 3 dimensional observation of the major intracranial vessels and their branches can provide noninvasively useful information on arteriovenous malformations, steno-occlusive diseases, cerebral aneurysms, tumors as well as moyamoya diseases<sup>4,6,7</sup>. Vascular compression of the facial and trigeminal nerves can be studied with useful information in more than 95% of the cases. Feeding arteries and draining veins of the tumors can be demonstrated in some cases. MR angiography is particularly advantageous in children, since the use of contrast media is limited or contraindicated. It is important that contrast media is not necessary and radiation exposure can be avoided especially in pregnant women and children.

The most important disadvantage of this technique is lower spatial resolution<sup>4,6,7</sup>. The first order vessels such as the anterior, middle and posterior cerebral arteries as well as the circle of Willis are shown to good advantage, however, the second order vessels are often difficult to visualize and small arterial branches can not be shown with certainty in some cases. Secondly, there are often associated intravascular signal voids in the presence of rapid and complex flow, especially in the feeding arteries of the arteriovenous malformation and marked stenosis, as well as in the area where turbulent flow is observed like the bifurcation of the vessels or the origin of the aneurysms. Motion compensation pulse sequences and short echo time may decrease the difficulties arising from intravascular signal voids; however, with the present technique, these artifacts are the most disturbing artifacts in the diagnosis of vascular diseases.

Another disadvantage of the present technique is a small imaging volume and distant vascular territories such as the vertex, the anterior and posterior aspect of the brain as well as the skull base are difficult to evaluate especially in patients with a large lesion.

An additional disadvantage of this technique is the fact that it is not possible to obtain pathophysiologic information from MR angiography unlike conventional angiography, which provides arterial,

capillary and venous circulation. It is not possible to perform sequential imaging of the collateral vessels and neovascularity as the flow of contrast media takes place.

Two techniques of MR angiography have inherent advantages and disadvantages<sup>4,6,7,12,13)</sup>. The major advantages of the time of flight technique over the phase contrast technique includes shorter imaging time, least signal loss due to turbulent and complex flow, and insensitiveness to flow induced phase shift, whereas disadvantages have been difficulties in demonstrating slow flow and distal arteries, overestimation of arterial stenoses and presence of artifacts due to shortened T1 substances such as Gd-DTPA enhancing lesions and hematoma. In contrast, there is uniform flow sensitivity with good contrast and better visualization of small arteries and veins for phase contrast angiography. However, disadvantages of the latter technique includes longer acquisition time, more signal loss due to turbulent and complex flow and requirement of more intensive post-processing.

With further technical developments, this technique will be used in MR angiography of other parts of the body more widely<sup>14)~16)</sup>.

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