3D time-of-flight (TOF) MR angiography (MRA), the most common MRA technique in an acute stroke setting, is useful for evaluating intracranial steno-occlusive disease. However, TOF is insensitive to slow flow or in-plane flow because of saturation of the MR imaging signal intensity, which can lead to overestimating the severity of the stenosis or to a false diagnosis of vascular occlusion. The use of MR imaging contrast agents shortens the T1 relaxation time of blood, decreases the saturation effects, and increases the steady-state signal intensity of blood. Although previous reports mention that postcontrast 3D TOF MRA demonstrates slow-flow vessels, thus avoiding overestimation of vascular obstruction, accuracy of postcontrast 3D TOF MRA has not been assessed on the basis of the results of conventional angiography.

The purpose of this study was to correlate pre- and postcontrast 3D TOF MRA with the results of conventional angiography during endovascular reperfusion therapy and to determine the accuracy of postcontrast 3D TOF MRA.

**RESULTS:** In 2 of 5 patients with arterial stenosis and 6 of 8 patients with complete occlusion, MRA signal intensity proximal to each lesion was absent, indicating a proximal pseudo-occlusion on precontrast MRA. Postcontrast MRA demonstrated an arterial signal intensity proximal to the stenotic or occlusive lesions in all 13 patients. Arterial signal intensity distal to the occlusion was identified on postcontrast MRA in 7 of 8 patients having complete occlusion, and the extent of occlusion on postcontrast MRA was similar to results of conventional angiography.

**CONCLUSION:** In this small series, postcontrast 3D TOF MRA more accurately delineated the extent of stenotic or occlusive arterial lesions than precontrast MRA.
1-mm gap; 23 × 16 cm FOV; and a 128 × 89 acquisition matrix reconstructed to a 128 × 128 matrix. We collected 950 images over 70 seconds during intravenous administration of a 0.2-mL/kg bolus of gadodiamide hydrate (Omniscan, Daiichi Pharmaceutical, Tokyo, Japan) injected at the rate of 4 mL/s. The hypoperfused area was determined on the basis of the mean transit time map generated from PWI postprocessing.

Postcontrast MRA using the same location and coverage as precontrast MRA was performed immediately after PWI. Data were transferred to an independent workstation, and subvolumes were generated. Pre- and postcontrast MR angiograms were displayed by using a maximum intensity projection (MIP) algorithm. Postcontrast MRA required additional subvolumes to erase the superficial middle cerebral vein, other prominent cortical veins, dural sinuses, and nasal mucosa. Because the cavernous ICA was surrounded by enhanced cavernous sinus and was obscured on MIP images, sagittal multiplanar reconstruction images were also used for the evaluation.

If there was a PWI/DWI mismatch, percutaneous transluminal cerebral balloon angioplasty (PTCBA) or intra-arterial thrombolysis was indicated. The patients and their relatives were informed about the hazards of reperfusion therapy as well as its potential benefit and, thus, the risk of not being treated. From April 2004 to November 2005, a total of 13 patients agreed to have interventional reperfusion therapy and were included in this study. The 13 patients comprised 5 women and 8 men ranging from 51 to 88 years of age (mean, 67 years of age).

Reperfusion Therapy
All 13 patients underwent reperfusion therapy under local anesthesia via a femoral artery. Heparin (3000 U) was injected intravenously to avoid thrombus formation during the procedure. A guidewire was navigated across the occlusion or stenosis and advanced into the distal segment. In 9 patients who underwent PTCBA, a balloon catheter (Gateway, Boston Scientific/Target Therapeutics, Fremont, Calif) was guided over the wire and then inflated to the nominal pressure for 30 seconds. In the remaining 4 patients, a microcatheter (Renegade, Boston Scientific/Target Therapeutics) was inserted into and distal to the thrombus and 72,000–240,000 U of urokinase was slowly injected by hand. Selective angiography during PTCBA or thrombolysis was also performed to clarify the extent of the lesion and as a standard of reference for image analysis.

Image Review
Two senior neuroradiologists (H.I. and M.M.), who were blinded to the results of MRA, analyzed and interpreted the conventional angiography results on a PACS station through consensus. The vessel patency on conventional angiography was graded according to the Thrombolysis in Myocardial Infarction (TIMI) criteria:

- TIMI grade 0 flow indicates complete occlusion; TIMI grade 1 flow denotes some penetration of the obstruction by contrast material, but no perfusion of the distal vascular bed; TIMI grade 2 flow denotes perfusion of the entire distal vascular bed, but with delayed flow compared with that of a normal artery; and TIMI grade 3 flow denotes full perfusion with normal flow. The extent of complete obstruction was determined by superselective angiography beyond the lesion or angiography after PTCBA.

The results of pre- and postcontrast MR angiography were also evaluated by consensus by 2 senior neuroradiologists (H.I. and M.M.), who knew the results of conventional angiography. Arterial sections were divided into 2 segments on the basis of the results of the conventional angiography, either proximal or distal to the lesion. Ar-
arterial signal intensity on MRA was graded as 0 for absent, 1 for diminished or narrowed, or 2 for normal.

### Results

Arterial signal intensity on pre- and postcontrast MRA is listed in the Table.

#### Stenosis (TIMI Grades 1 and 2)

Angiographically, 1 patient was graded as TIMI 2, and 4 patients were graded as TIMI 1. In 2 of these 5 patients, arterial signal intensity faded on the proximal side of each lesion, showing proximal pseudo-occlusion on precontrast MRA (Fig 1). Arterial signal intensity distal to the lesions was not identified in these 2 patients. In the remaining 3 patients, arterial signal intensity was identified both proximal and distal to the lesions. Postcontrast MRA delineated an arterial signal intensity proximal and distal to each lesion, which enabled us to precisely evaluate the extent of stenosis in all 6 patients.

#### Occlusion (TIMI Grade 0)

Angiographically, 8 patients were graded as TIMI 0. In 2 of these 8 patients, arterial signal intensity was identified proximal to each lesion (Fig 2); however, in the remaining 6 patients, arterial signal intensity faded on the proximal side of the lesions, causing suspicion of more proximal occlusions on precontrast MRA. Arterial signal intensity distal to the lesion was not identified on precontrast MRA in any of these 8 pa-
tients. Postcontrast MRA delineated arterial signal intensity just proximal to the lesions in all 8 patients. Arterial signal intensity distal to lesions was identified (normal or narrowed) on postcontrast MRA in 7 of 8 patients (Fig 2). In these patients, the extent of occlusion on postcontrast MRA was similar to that found on superselective angiography during PTCBA or thrombolysis. In the remaining 1 patient, the vessel distal to the occlusion was not included in the scanning range of MRA.

Discussion

The purpose of MR imaging in an acute stroke setting is to demonstrate the extent of irreversible ischemic brain damage, tissue at risk, and the causative arteriopathy of ischemic stroke and its extent. Although an excellent correlation between the findings of MRA and those of conventional angiography has been reported for detecting intracranial vascular alterations, unenhanced MRA has some limitations in diagnostic accuracy because of its relative insensitivity to slow flow. This series included only 13 patients; however, it is evident that precontrast TOF MRA did not always show the correct lesion location and center. Angiography demonstrated a delayed washout of contrast proximal to lesions, suggesting slow-flow, which is thought to be related to signal-intensity loss on TOF MRA. The use of MR imaging contrast agents shortens the T1 relaxa-
tion time of blood, and improves the delineation of perfusion in the entire MCA territory and had a poor prognosis.

In patients with poor collateral circulation, therefore, the distal portion of an occluded vessel segment might not be delineated on postcontrast MRA.

We did not use multiple overlapping thin-slab acquisitions because slab boundary artifact was inevitable with our equipment. Multiple overlapping thin-slab acquisitions minimizes flow saturation and will improve delineation of slow flow, but very slow flow will lose its signal intensity on TOF MRA. We expect that adding MR imaging contrast to multiple overlapping thin-slab acquisitions further improves delineation of slow flow.

In conclusion, postcontrast MRA delineates vascular stenosis or occlusion associated with acute ischemic stroke more accurately than precontrast MRA. Postcontrast MRA also provides information about the vessels distal to a lesion, which is useful for planning interventional therapy.

References

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