Symptomatic Isolated Middle Cerebral Artery Dissection: High Resolution MR Findings
증상이 있는 중대뇌동맥 박리의 고해상도 자기공명영상 소견 분석

Jung Hee Byon, MD¹, Hyo Sung Kwak, MD¹,²*, Gyung Ho Chung, MD¹,², Seungbae Hwang, MD¹,²

¹Department of Radiology, Chonbuk National University Medical School, Jeonju, Korea
²Research Institute of Clinical Medicine, Chonbuk National University Hospital, Jeonju, Korea

**Purpose:** To perform high-resolution magnetic resonance imaging (HRMRI) and determine clinical features of patients with acute symptomatic middle cerebral artery (MCA) dissection.

**Materials and Methods:** Thirteen patients with acute symptomatic MCA dissection underwent HRMRI within 3 days after initial clinical onset. They also underwent routine brain MR imaging. HRMRI examinations included time-of-flight MR angiography (MRA), T2-weighted, T1-weighted, proton-density-weighted, and three-dimensional magnetization-prepared rapid acquisition gradient-echo (MPRAGE) sequences. Conventional angiography and MRA were used as reference standard to establish the diagnosis of MCA dissection. The angiographic findings and HRMRI findings such as intimal flap, double lumen, and intramural hematoma were analyzed in this study.

**Results:** All patients presented cerebral ischemia (median National Institutes of Health Stroke Scale score = 4, range = 0–18). String sign was seen on MRA in seven patients. However, double lumen was seen in all patients on HRMRI by intimal flap. High signal lesion on MPRAGE sequences around the dissection lumen due to intramural hematoma was seen in three patients.

**Conclusion:** HRMRI can be used to easily detect the wall structure of MCA such as the intimal flap and double lumen in patients with acute symptomatic MCA dissection. MPRAGE can detect hemorrhage in false lumen of MCA dissection.

**Index terms**
Middle Cerebral Artery
Dissection
Stroke

**Received** April 3, 2015  
**Revised** June 13, 2015  
**Accepted** July 23, 2015  
*Corresponding author: Hyo Sung Kwak, MD  
Department of Diagnostic Radiology, Chonbuk National University Medical School and Hospital, 20 Geonji-ro, Deokjin-gu, Jeonju 54907, Korea.  
Tel. 82-63-250-1150  Fax. 82-63-272-0481  
E-mail: kwak8140@jbnu.ac.kr

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fined cross-sectional and longitudinal analysis of morphologic features of MCA (6-9). Increased signal-to-noise ratio at 1.5 T or 3.0 T allows for high spatial resolution, permitting detailed analysis of diseased vessel segment. Thus, an unequivocal distinction between intramural hematoma and thrombus is possible. Information could be gained with regard to the degree of stenosis, the formation of pseudoaneurysm, and the appearance of new dissections in patients with acute MCA dissection. The aim of this study was to obtain HRMRI findings compared to angiographic MR findings and determine the clinical features of patients with acute symptomatic MCA dissection.

**MATERIALS AND METHODS**

**Patients**

Institutional Review Board approval was obtained for this retrospective study. Informed consent was waived. A total of 121 consecutive patients with acute ischemic stroke and occlusion or stenosis of MCA from January 2011 to September 2014 were included in this study. The diagnosis of MCA dissection was made by consensus of stroke specialists and neuroradiologists at our institute based on clinical and radiologic features. Clinical features were sudden onset of ischemic or hemorrhagic symptoms. Radiological features suggestive of MCA dissection included one or more of the following characteristic signs on MRA or digital subtraction angiography (DSA) or HRMRI: a double lumen sign, a pearl-and-string sign (alternating widening and narrowing), string sign (stenosis), and intimal flap with false lumen. A total of 13 patients who met our study criteria were used in our final analysis. These patients underwent stroke MR imaging within 6 hours after clinical onset. They also underwent HRMRI within 2 days after stroke MR imaging. The following clinical data were collected from these patients: age, sex, initial symptom, National Institutes of Health Stroke Scale (NIHSS) score at admission, traumatic history, past history (hypertension, smoking, diabetes, and hyperlipidemia), and treatment methods. Clinical outcome was assessed using NIHSS and modified Rankin Scale when a patient was discharged from the hospital.

**MR Imaging Protocol**

HRMRI was performed with a 3-tesla MRI scanner (Achieva; Philips Medical Systems, Best, the Netherlands) using a 32-channel head coil. All patients initially underwent stroke MR imaging including three-dimensional time-of-flight (TOF)-MRA. TOF-MRA was obtained in the axial plane. Data were reconstructed using a dedicated online post-processing tool to determine the blood vessel architecture.

HRMRI was included in the following four different scans using black blood technique: T1-weighted, T2-weighted, proton density-weighted, and magnetization-prepared rapid acquisition gradient-echo (MPRAGE). The black blood technique with pre-regional saturation pulses of 80 mm thickness to saturate incoming arterial flow was used for all scans. Parameters of each sequence were summarized in Table 1.

**Imaging Analysis**

Image analysis was performed on a workstation (SyngoVia; Siemens, Erlangen, Germany). This study used color map function of SyngoVia program for lesion morphology. First, we analyzed stroke MR and conventional angiographic findings such as lesion sites, location of infarction, and MRA findings (double lumen, stenosis with dilatation, and stenosis). Second, HRMRI

| Table 1. Parameters of Each Sequence |
|------------------------------------|
| **Parameter** | **3D TOF** | **T1-BB** | **T2-BB** | **PD-BB** | **MPRAGE** |
| TR (msec) | 22 | 700 | 1800 | 1800 | 1240 |
| TE (msec) | 3.9 | 23 | 78 | 26 | 3.4 |
| FOV (mm) | 195 × 215 | 100 × 125 | 100 × 125 | 100 × 125 | 125 × 125 |
| Matrix | 448 × 284 | 256 × 204 | 256 × 204 | 256 × 204 | 256 × 204 |
| Number of signals acquired | 1 | 4 | 4 | 4 | 1 |
| Slice thickness (mm) | 0.5 | 2 | 2 | 2 | 1.5 |
| Echo train length | 1 | 6 | 16 | 16 | 1 |
| Number of slices | 150 | 10–11 | 10–11 | 10–11 | 64 |
| Scan time (min) | 4 | 3–4 | 3–4 | 3–4 | 3 |

3D TOF = three dimensional time-of-flight, BB = black blood, FOV = field of view, MPRAGE = magnetization-prepared rapid acquisition gradient-echo, PD = proton-density, TE = echo time, TR = repetition time
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images were analyzed for abnormalities of the artery wall and lumen such as double lumen, intimal flap, and hemorrhage into the false lumen. These factors were evaluated based on consensus between two neuroradiologists.

Intimal flap was identified as a linear signal intensity that divided the lumen into double lumen. If the linear signal intensity was continuous over the vessel wall, it was considered as an artifact. Differential diagnosis included atherosclerosis without intraplaque hemorrhage and vasculitis. Atherosclerosis without intraplaque hemorrhage was identified as wall thickening that had iso-signal intensity compared to adjacent muscle. In addition, there was no double lumen. Vasculitis was identified as circumferential wall enhancement on enhanced T1 sequence.

Hemorrhage in the false lumen was detected by high signal intensity in the false lumen on MPRAGE sequence. Its differential diagnosis was intraplaque hemorrhage whose signal intensity was less bright and vague due to stagnant blood product.

RESULTS

The basic clinical characteristics of the 13 cases of MCA dissection and treatment methods are shown in Table 2. Their median age was 57 years old, ranging from 42 to 72 years old. Of these patients, 12 (92.3%) did not have any traumatic history. Only one case presented traumatic history related to a car accident 3 months ago. Ten (76.9%) patients had acute ischemic symptoms such as hemiparesis, dysarthria, or weakness. Three patients had symptoms similar to transient ischemic attack. The median NIHSS score at admission was 2 (range, 0–18). Four patients received IV recombinant tissue plasminogen activator. All patients underwent cerebral angiography for examination or occlusion treatment or MCA stenosis.

Stroke MR and MRA findings of this study are summarized in Table 3. Nine (69.2%) patients had MCA dissection at the left side. Three (23.1%) patients had complete obstruction of MCA on initial MRA with high NIHSS score at admission. Of the three patients with complete obstruction of MCA on initial MRA, two underwent conventional angiography for endovascular treatment of MCA lesion. The other one underwent medical treatment because of delayed admission after symptom onset. Ten (76.9%) patients had a diffusion restriction on diffusion weighted imaging. Vessel segment of involved MCA dissection was short (< 1 cm) in ten (76.9%) patients. No patient had a sign of intracranial hemorrhage (ICH) or subarachnoid hemorrhage (SAH) related to MCA dissection.

The findings of MCA dissection on HRMRI, MRA, and conventional angiography are summarized in Table 4. Eight (61.5%) patients had positive dissection findings such as string sign, pearl string sign, and double lumen on MRA. Five patients including three with complete obstruction did not show any MRA findings.

| No. | Age/Sex | Cause | Initial Symptoms | Initial NIHSS | HTN | Smoking | Diabetes | Hyperlipidemia | Treatment |
|-----|---------|-------|------------------|--------------|-----|---------|----------|----------------|-----------|
| 1   | 42/M    | Spontaneous | Hemiparesis, dysarthria | 11          | -   | -       | -        | -              | Medical   |
| 2   | 46/M    | Spontaneous | Hemiparesis | 10          | -   | -       | -        | -              | Medical   |
| 3   | 64/F    | Spontaneous | Dysarthria | 2           | +   | -       | +        | -              | Medical   |
| 4   | 61/F    | Spontaneous | Weakness | 0           | +   | -       | -        | -              | Medical   |
| 5   | 54/F    | Spontaneous | TIA | 0           | -   | -       | -        | +              | Medical   |
| 6   | 60/M    | Spontaneous | TIA | 0           | +   | +       | -        | -              | Medical   |
| 7   | 56/F    | Traumatic* | Dysarthria | 2           | -   | -       | +        | Stent          | Medical   |
| 8   | 60/F    | Spontaneous | Hemiparesis, dysarthria | 6          | -   | -       | -        | -              | Medical   |
| 9   | 72/M    | Spontaneous | Hemiparesis, dysarthria | 18         | -   | +       | -        | -              | Medical   |
| 10  | 51/F    | Spontaneous | TIA, dizziness | 0           | -   | -       | -        | -              | Medical   |
| 11  | 55/F    | Spontaneous | Hemiparesis, dysarthria | 11         | -   | -       | -        | -              | Medical   |
| 12  | 61/M    | Spontaneous | Hemiparesis, dysarthria | 13         | -   | +       | -        | -              | Medical   |
| 13  | 57/F    | Spontaneous | Dysarthria | 4           | -   | -       | -        | -              | Medical   |

*Traumatic symptoms: symptoms related with a history of car accident 3 months ago.
HTN = hypertension, NIHSS = National Institutes of Health Stroke Scale, No. = number, TIA = transient ischemic attack
for the diagnosis of MCA dissection. Seven (53.8%) patients had string sign on conventional angiography. Five had a pearl-string sign. Five had a double lumen sign. Three patients showed focal eccentric stenosis of MCA on initial conventional angiography. All (100%) patients, including the three with complete obstruction on MRA, showed intimal flap and double lumen findings on HRMRI (Fig. 1). Three (23.1%) patients had focal hemorrhage in the false lumen on MRPRAGE sequence of HRMRI (Fig. 2).

**DISCUSSION**

The main finding of this study was that all patients with acute MCA dissection had HRMRI findings of intimal flap and double lumen. However, only some patients had focal hemorrhage in the false lumen.

Intracranial dissection is an important cause of stroke, particularly in young individuals. Most intracranial dissections have been reported to involve the extracranial carotid and vertebral arteries. The annual incidence of carotid artery dissection is 2.5–3 per 100000 and that of vertebral artery dissection is 1–1.5 per 100000 (10). In clinical practice, isolated MCA dissection is an extremely rare clinical entity. Although the etiology of MCA dissection is trauma in some cases, the etiology in most patients is uncertain or idiopathic (1). In our study, nine (90%) patients, ex-
Patients with intracranial dissection are relatively young. They commonly have ischemia or SAH. Asaithambi et al. (11) has reported analyzed studies and case reports on isolated MCA dissection. Literature review yielded 61 cases [62.3% male, median age 46 years (range, 1.66–79)] from 54 published case reports/series of isolated MCA dissection. Approximately 14.8% \((n = 9)\) of cases occurred from traumatic injury. A total of 28 (45.9%) patients were younger than 45 years old, whereas 33 (54.1%) patients were older than 45 years. Approximately 27.9% \((n = 17)\) of patients were 45–59 years old. However, 26.2% of patients \((n = 16)\) were older than 60 years. In patients whose cause was traumatic injury, their median age was 25 years (range, 15–56 years). In this study, only one patient (case 7) had trau-

**Fig. 1.** A 60-year-old woman with left MCA dissection and acute infarction of the basal ganglia (case 8).

A. Diffusion weighted imaging showing diffusion restriction of the basal ganglia and multifocal focal infarction in the MCA territory.

B. MRA showing severe stenosis of the left MCA (arrow).

C. Cerebral angiography showing eccentric focal stenosis on the MCA (arrow).

D. Proton density-weighted HRMRI showing intimal flap in the left MCA (arrow).

HRMRI = high-resolution magnetic resonance imaging, MCA = middle cerebral artery
matic injury. A total of 54% ($n = 7$) patients was 45–59 years whereas only 46% ($n = 6$) of patients was older than 60 years. Age distribution was different. This could be due to the fact that traumatic cause was rare. Ohkuma et al. (12) has reported the neuroradiological and clinical features of patients with dissection aneurysms of MCA. In this study, 9 (69.2%) of 13 patients with dissection aneurysms of MCA presented bleeding events such as SAH and/or ICH, while 4 presented ischemia. Li et al. (1) has reported that the dissection of anterior circulation typically will manifest as ischemia. However, dissection of posterior circulation usually manifests as SAH. In our study, 7 (70%) patients with MCA dissection had acute ischemic symptoms related to multifocal or massive lobar infarction without SAH or ICH associated with the dissection and stenosis or occlusion without aneurysmal dilatation.

Typical angiographic findings of MCA dissection are similar
to those observed with dissection of extracranial arteries, including string sign, irregular stenosis, pseudoaneurysm, and total occlusion (12, 13). Angiographic finding of a double lumen with the presence of an intimal flap (string sign) is relatively common (12). However, findings of pseudoaneurysm or occlusion are relatively uncommon. Segmental stenosis of involved vessel segment is the most common findings. In our study, ten (76.9%) patients had a segment stenosis of the MCA and three (23.4%) had complete occlusion on MRA. Three patients with complete obstruction of the involved vessel segment on initial MRA were diagnosed as acute stroke by MCA occlusion. These patients were diagnosed with MCA dissection by findings such as pearl string sign and string sign on cerebral angiography. In this study, one case (case 1) had negative finding in both DSA and MRA. However, MCA dissection was diagnosed because there were suggestive findings in HRMRI such as double lumen and intimal flap. Even though DSA was considered as a gold standard for diagnosing MCA dissection, it cannot show an internal structure of the involved vessel. On the other hand, HRMRI can show internal structures such as intimal flap that is a direct cause of dissection. Therefore, it is reasonable to diagnose MCA dissection by HRMRI in patients who had negative findings on both DSA and MRA.

Recently, HRMRI has emerged as a potentially useful technique for atherosclerotic plaque imaging in MCA (6-9). HRMRI sequences including MPRAGE have successfully eliminated the flowing blood signal, allowing the assessment of lumen of stenotic intracranial artery and the depiction of atherosclerotic plaque in MCA. In addition, the high signal-to-noise ratio and minimal scan duration offer great advantages in clinical settings. In our study, all patients had double lumen by the intimal flap without dilatation in the MCA on HRMRI.

Hemorrhage in the false lumen of patients with arterial dissection is a common finding. Our HRMRI protocol included MPRAGE sequence for detecting intraplaque hemorrhage or hemorrhage in the false lumen of MCA dissection. Compared to T1 or TOF sequences, MPRAGE demonstrated higher diagnostic capability for the detection and quantification of intraplaque hemorrhage (14). Turan has reported that abnormal intraplaque T1 signal compatible with hemorrhage or blood products is equal to or higher than 150% of T1 signal of adjacent muscle (15). In our study, three patients had high signal intensity compatible with hemorrhage in the false lumen of MCA dissection on MPRAGE sequence.

In conclusions, we were able to easily detect double lumen by intimal flap in patients with MCA dissection on HRMRI. In addition, we were able to detect hemorrhage in false lumen of MCA dissection on MPRAGE sequence. Further studies are required to investigate the clinical outcomes of patients with MCA dissection and the serial changes of involved vessel segment of MCA dissection on HRMRI.

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증상이 있는 중대뇌동맥 박리의 고해상도 자기공명영상 소견 분석

변정희1·곽효성1·2*·장경호1·2·황승배1·2

목적: 급성 증상이 있는 중대뇌동맥 박리 환자들의 고해상도 자기공명영상 소견을 분석하고자 하였다.

대상과 방법: 급성 중대뇌동맥 박리로 진단받은 13명의 환자들은 모두 증상이 시작된지 3일 이내에 고해상도 자기공명 사전을 활용하였다. Three-dimensional (이하 3D) time-of-flight magnetic resonance angiography, T2 강조영상, T1 강조영상, 양성자밀도강조영상, 3D magnetization-prepared rapid acquisition gradient-echo (이하 MPRAGE)를 사용하였다. 전통적 뇌혈관조영술과 자기공명혈관조영술을 이용하여 중대뇌동맥 박리를 진단하였다. 내막절편, 이중내강(double lumen), 벽성혈종(intramural hematoma) 같은 영상 소견을 분석하였다.

결과: 모든 환자는 뇌혈관 허혈 증상을 보였다(median National Institutes of Health Stroke Scale score = 4, range = 0~18). 자기공명혈관조영술에서 7명은 염주모양(string of beads sign)을 보였다. 반면, 고해상도 자기공명영상에서는 모든 환자가 내막절편으로 인한 이중내강(double lumen)을 보았다. MPRAGE sequence에서 3명의 환자가 벽성혈종으로 인해 가상내강(false lumen) 내부에 고신호강도를 보였다.

결론: 고해상도 자기공명영상은 급성 증상이 있는 중대뇌동맥 박리 환자들에서 혈관 내막 이상소견을 확인하는 데 유용하다. 그리고 MPRAGE는 중대뇌동맥 박리의 벽성혈종을 구분하는 데 도움이 된다.

1전북대학교 의학전문대학원 영상의학과학교실, 2전북대학교병원 임상의학연구소