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Clinical Article

Middle Cerebral Artery Duplication : Classification and Clinical Implications

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Objective : Although there are several explanations for a duplicated middle cerebral artery (DMCA), its embryological origin is still an open question. We reviewed these anomalous vessels to postulate a theory of their different origins, sizes, and courses.
Methods : A retrospective review of 1,250 cerebral angiographies, 1,452 computed tomography (CT)-angiographies, and 2,527 magnetic resonance (MR)-angiographies was performed to identify patients with DMCA.
Results : Twenty-five patients had 25 DMCAs. Conventional angiography detected nine patients with DMCA (9/1250, 0.72%), MR-angiography detected seven patients with DMCA (7/2527, 0.28%), and CT-angiography detected nine patients with DMCA (9/1452, 0.62%). The DMCAs originated near the internal carotid artery terminal in eight patients (type A), and between the origin of the anterior choroidal artery and the terminal internal carotid artery in 17 patients (type B). The diameters of the eight type A DMCAs were the same or slightly smaller than those of the other branch of the DMCA. All type A DMCAs showed a course parallel to that of the other branch of the DMCA. The diameters of the 17 type B DMCAs were the same, slightly smaller, or very much smaller than that of the other branch of the DMCA. Nine type B DMCAs showed parallel courses, and the other eight curved toward the temporal lobe.
Conclusion : The two branches of the type A DMCAs can be regarded as early bifurcations of the MCA. The branches of the type B DMCAs had parallel courses or a course that curved toward the temporal lobe. The type B DMCA can be regarded as direct bifurcations of the MCA trunk or the early ramification of the temporal branch of the MCA.

Key Words : Duplication · Middle cerebral artery · Clinical implications.

INTRODUCTION

A duplicated middle cerebral artery (DMCA) is an anomalous vessel arising from the internal carotid artery (ICA). The origin of the DMCA lies between the anterior choroidal artery and the distal end of the ICA. Although there are several explanations of DMCA[9,13,18], its embryological origin is still an open question. Komiyama et al.[13] proposed that the development of DMCA involves the anomalously early ramification of the early branches of the middle cerebral artery (MCA), based on their similarity to the cortical supply by the early branches of the MCA. Yamamoto et al.[18] suggested that DMCA is a variant of the normal branching of the MCA. Kai et al.[9] reported two types of DMCA : one with a course parallel to that of the main MCA (type A) and the other coursing toward the temporal lobe (type B).

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We identified several DMCAs with conventional angiography, computed tomography (CT)-angiography, and magnetic resonance (MR)-angiography. We evaluated the courses of the DMCAs in the sylvian cistern with MR-angiography and analyzed the spatial relationships of the DMCAs with CT-angiography. We found that type A DMCAs had courses parallel to those of the other branch of the DMCA, whereas type B DMCAs were divided into two types : those with parallel branches and those with branches that curved toward the temporal lobe.

We describe the characteristics (their different origins, sizes, and courses) of DMCA on conventional angiography, CT-angiography, and MR-angiography for the classification of DMCAs. We also review the clinical implications of DMCA, especially aneurysms located at the origin of the DMCA and cerebral infarction caused by DMCA occlusion.

MATERIALS AND METHODS

We retrospectively reviewed conventional cerebral angiograms to identify patients with DMCA. Conventional cerebral angiography (Philips V-3000, Philips Medical System, Eindhoven, Netherlands) was performed in 506 patients between April 1, 2000, and

September 30, 2006 at hospital A. In addition, conventional cerebral angiography (Philips V-5000) was also performed in 744 patients between July 1, 1997, and August 31, 2006, at hospital B.

We retrospectively reviewed the results of 2527 MR-angiographies performed between August 1, 2003, and December 31, 2007, in the hospital A to identify patients with DMCA. For the MR-angiography (1.5 T; Intera Achieva, Philips Medical System) studies, a three-dimensional time-of-flight (TOF) technique was used with a neurovascular phased array coil (SENSE-Head-8, Philips Medical System). A multiple-overlapping thin-slab acquisition technique was used. The following imaging parameters were selected : repetition time, 23 ms; echo time, 6.9 ms; field of view, 180×180 mm; number of slices, 120; slice thickness, 0.7 mm; slab thickness, 84 mm; imaging matrix, 384 ×512; number of excitations, 1. No intravenous paramagnetic contrast agent was administered to any of the patients. In each patient, a total of 20 maximum-intensity-projection images in the frontal view (both from left lateral to right lateral 180° and craniocaudally 180°) were routinely displayed stereoscopically.

We also retrospectively reviewed 1452 CT-angiographies that had been performed between January 1, 2009, and October 31, 2010, in the hospital A to identify patients with DMCA. CT-angiography was performed with a Toshiba CT scanner (Toshiba Aquilion TSX-101A 64 Channel; Toshiba Medical Systems, Tokyo, Japan). The following imaging parameters were selected: CT configuration, 64×0.5 mm; contrast amount, 100 mL of Iobrix 350 (Iohexol, Taejoon Pharmaceuticals Co. Ltd, Seoul, Korea) by automated antecubital venous infusion; contrast infusion rate, 2.0 mL/s; reconstructed section thickness and section interval, 5 mm with no interval; CT matrix, 512×512; 120 kilovolts (kVp); 100 milliamps (mA); field of view, 64×64 mm.

The initial angiographic, CT-angiographic, and MR-angiographic studies were performed for a variety of clinical reasons, including symptoms of cerebral ischemia, hemorrhagic contusion, intracerebral hemorrhage, headache, dizziness, and routine check-up. In patients with DMCA, special attention was given to defining the origin, diameter, course, and spatial relationships with the structures surrounding the vessel.

We divided the DMCAs into two types according to the classification of Kai et al.[9]. Type A DMCA originated from the top of the ICA, and type B DMCA separated between the top of the ICA and the anterior choroidal artery.

RESULTS

Twenty-five patients had 25 DMCAs. Conventional angiography detected nine patients with DMCA (9/1250, 0.72%), MR-angiography detected seven patients with DMCA (7/2527, 0.28%), and CT-angiography detected nine patients with DMCA (9/1452, 0.62%). Eight patients had type A DMCAs (Table 1), and 17 patients had type B DMCAs (Table 2). Eight type A DMCAs were identified in one conventional angiography (1/1250, 0.08%), three MR-angiographies (3/2527, 0.12%), and four CT-angiographies (4/1452, 0.28%). And 17 type B DMCAs were identified in eight conventional angiographies (8/1250, 0.64%), four MR-angiographies (4/2527, 0.16%), and five CT-angiographies (5/1452, 0.34%). Tables 1 and 2 show the radiological and clinical characteristics of the patients with DMCAs.

The diameters of the eight type A DMCAs were the same (four cases) or slightly shorter (four cases) than those of the other branches of the DMCAs. All type A DMCAs had courses that were parallel to those of the other branches of the DMCAs (Fig. 1). In one patient with type A DMCA, MR-angiography, which was used to evaluate headache and left arm numbness, showed almost no flow in the superior division of the DMCA. MR-angiography performed two years and eight months earlier showed normal flow in both divisions of the DMCA (Fig. 2). The 17 type B DMCAs had diameters that were the same (six cases), slightly smaller (four cases), or very much smaller (seven cases) than those of the other branches of the DMCAs. Nine type B DMCAs showed parallel courses for both branches (Fig. 3), and eight type B DMCAs showed a curved course toward the temporal lobe (Fig. 4).

DISCUSSION

Origin, size, and type of DMCA

According to the classification system proposed by Teal et

Table 1. Summary of eight patients with type A duplicated middle cerebral artery

Case	Age/Sex	Course of DMCA	Site	Image	Dx	Size of DMCA
1	F/73	Parallel	RT	MRA	TIA	Same
2	F/62	Parallel	LT	MRA	SAH, infarction	Same
3	M/70	Parallel	LT	MRA	Infarction	Slightly smaller
4	F/77	Parallel	LT	TFCA	SAH, infarction	Slightly smaller
5	M/28	Parallel	LT	CTA	Headache	Same
6	M/67	Parallel	LT	CTA	Chronic SDH	Slightly smaller
7	M/50	Parallel	RT	CTA	Cerebellar ICH	Slightly smaller
8	M/65	Parallel	RT	CTA	Cavernous sinus infection	Same

Parallel : parallel course with another duplicated middle cerebral artery, SAH : subarachnoid hemorrhage, TIA : transient ischemic attack, ICH : intracerebral hemorrhage, SDH : subdural hematoma, DMCA : duplicated middle cerebral artery, Dx : diagnosis, RT : right, LT : left, MRA : magnetic resonance angiography, CTA : computed tomography angiography, TFCA : trans femoral cerebral angiography, Size of DMCA : relative size compared with diameter of the other branches of the DMCA

Table 2. Summary of seventeen patients with type B duplicated middle cerebral artery

Case	Age/Sex	Course of DMCA	Site	Image	Dx	Size of DMCA
9	47/F	Curved	RT	TFCA	Headache	Same
10	59/F	Curved	LT	TFCA	SAH	Slightly smaller
11	52/M	Curved	RT	TFCA	Headache	Much smaller
12	54/F	Parallel	RT	TFCA	Headache	Same
13	38/F	Curved	LT	TFCA	SAH	Same
14	41/M	Curved	RT	TFCA	Headache	Much smaller
15	69/F	Curved	LT	TFCA	Infarction	Slightly smaller
16	59/F	Parallel	LT	TFCA	SAH	Same
17	56/F	Parallel	RT	CTA	Headache	Slightly smaller
18	33/F	Parallel	LT	CTA	Headache	Much smaller
19	54/M	Parallel	RT	CTA	3rd nerve palsy	Much smaller
20	55/F	Curved	RT	CTA	Headache	Much smaller
21	87/M	Parallel	LT	CTA	Infarction	Same
22	54/F	Parallel	RT	MRA	Chronic sinusitis	Slightly smaller
23	41/M	Parallel	LT	MRA	Headache	Much smaller
24	54/F	Curved	LT	MRA	Headache	Much smaller
25	58/M	Parallel	LT	MRA	TIA	Same

Parallel : parallel course with another duplicated middle cerebral artery, Curved : curved course to temporal lobe, SAH : subarachnoid hemorrhage, TIA : transient ischemic attack, DMCA : duplicated middle cerebral artery, Dx : diagnosis, RT : right, LT : left, MRA : magnetic resonance angiography, CTA : computed tomography angiography, TFCA : trans femoral cerebral angiography, Size of DMCA : relative size compared with diameter of the other branches of the DMCA

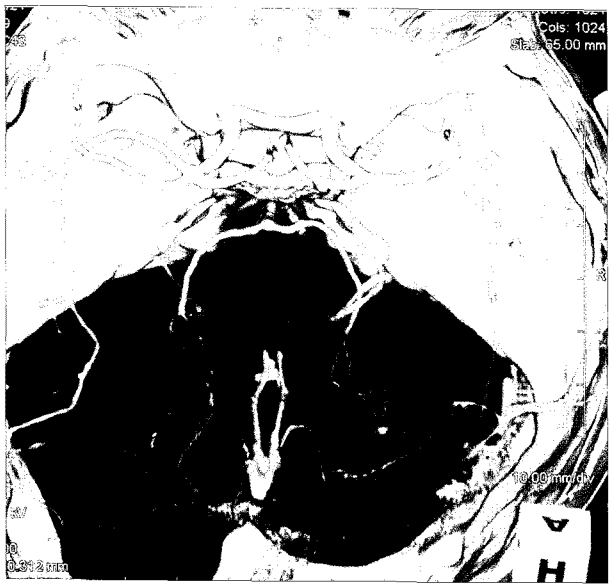

Fig. 1. Patient 5. Computed tomography-angiography. Left type A duplicated middle cerebral artery (DMCA) with a similar diameter to the other branch of the DMCA, originating from a point at the top of the left internal carotid artery. Its course is parallel to that of the other branch of the DMCA.

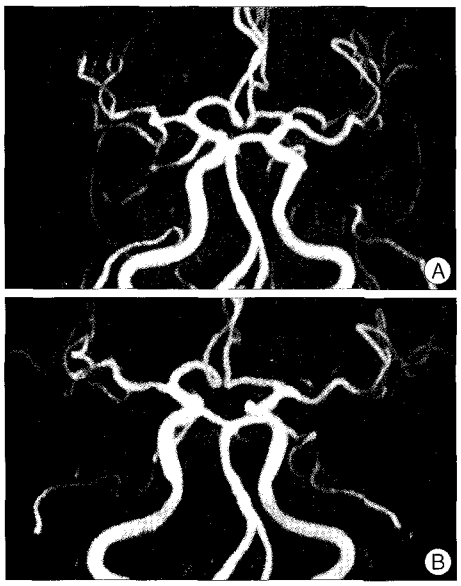

Fig. 2. Patient 3. Magnetic resonance (MR)-angiography of the left type A duplicated middle cerebral artery (DMCA). This DMCA has a slightly smaller diameter than that of the other branch of the DMCA and is originated from a point on the top of the left internal carotid artery. Its course is parallel to that of the other branch of the DMCA (A). MR-angiography performed two years and eight months after the first MR-angiography to evaluate headache and left arm numbness showed reduced flow in one branch of the DMCA (B).

al.[15], the development of DMCA requires an anomalous MCA to arise from the distal ICA. Several authors have described the origin of the DMCA. Some groups have suggested that a DMCA originates from the ICA at the exact level of the end of the ICA or at the anterior choroidal artery[6,17]. Other researchers have reported that the DMCA originates from the ICA between the anterior choroidal artery and the distal bifurcation of the ICA[3,13]. Kai et al.[9] divided DMCAs into two types according to their points of origin. Type A DMCAs originate from the top of the ICA, whereas type B DMCAs separate between the top of the ICA and the anterior choroidal artery. In our study, we identified eight DMCAs that separated near the top of the ICA and 17 DMCAs that originated between the anterior choroidal artery level and the ICA terminal.

There have been several reports of the sizes of DMCAs[9,13,17].

Fig. 3. Patient 17. Right type B duplicated middle cerebral artery originating between anterior choroidal artery and internal carotid artery terminal. This vessel shows a course parallel to that of the main middle cerebral artery.

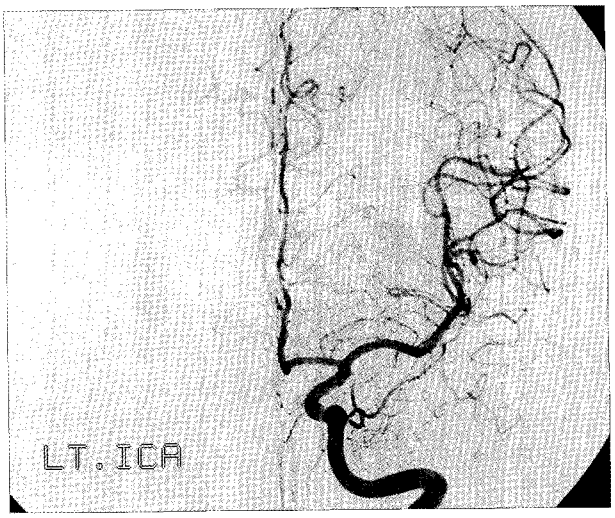

Fig. 4. Patient 10. Transfemoral cerebral angiography of type B left duplicated middle cerebral artery. This vessel originates between the anterior choroidal artery and the internal carotid artery terminal, and has a curved course toward the temporal lobe.

Umansky et al.[17] reported that the DMCA and the main MCA trunk had the same outer diameter (3.5 mm). In contrast, Komiyama et al.[13] proposed that the DMCA diameter is smaller than that of the main MCA trunk. Kai et al.[9] divided these vessels into two groups according to their diameter relative to that of the main MCA. The diameter of the type A DMCA is the same as that of the main trunk of the MCA, whereas the diameter of the type B DMCA is smaller than that of the main MCA. In our study, we found that the diameter of the type A DMCA was the same or slightly smaller than that of the other branch of the DMCA. However, the type B DMCA had a diameter that was the same as, slightly smaller than, or very much smaller than that of the other branch of the DMCA.

There are two theories regarding the cortical territory and course of DMCAs. One theory maintains that the DMCA can be regarded as an early temporal branch of the MCA[1,13]. Komiyama et al.[13] reported that the DMCAs in their series consistently reached the temporopolar and anterior and/or middle temporal territories. In these reports, the DMCAs were similar to the anterior temporal arteries. Nomura et al.[2] and Choi et al.[14] considered DMCAs to be the early bifurcation of the anterior temporal artery. Gibo et al.[6] also suggested that DMCAs are distributed to the temporopolar area and the anterior and middle temporal areas.

A second theory maintains that the DMCA arises as the direct bifurcation of the main trunk of the MCA. Yamamoto et al.[18] defined the DMCA as a 'direct bifurcation' because this anomalous artery branches directly from the ICA. Kai et al.[9] noted that the type A DMCA separates at the top of the ICA, giving the impression of an early bifurcation. This type A DMCA may arise from the direct bifurcation of the MCA because the anomalous artery branches directly from the ICA. Conversely, the type B DMCA is an anomalously early manifestation of an MCA branch.

In our study, all type A DMCAs showed a course parallel to that of the other branch of the DMCA. Nine type B DMCAs showed a course parallel to that of the other branch, whereas the other eight type B DMCAs had a curved course toward the temporal lobe. In our study, all type A and type B DMCAs with a parallel course could be regarded as direct bifurcations of the MCA trunk. The type B DMCAs with a curved course toward the temporal lobe can be regarded as an early temporal branch of the MCA.

Clinical significance

DMCAs themselves have no clinical significance. However, rare aneurysms have been reported at the origin of the DMCA[2-5,7,8,10-12]. It is unclear whether this association is a chance occurrence or is related by an unknown mechanism. Kai et al.[9] reported that all aneurysms associated with DMCAs were found at the origins of type B DMCAs. They insisted that type B DMCAs can be expected to be subject to higher hemodynamic stress and that this is a factor in the development of aneurysms on the type B DMCA.

We also reviewed all DMCAs associated with aneurysms originating at the origin of a DMCA[2,9-11]. In most of these cases, the DMCAs were type B. However, one aneurysm associated with a DMCA arose from the trunk of the DMCA[16]. Another aneurysm was associated with a type A DMCA[12]. Contrary to the description of Kai et al.[9], type B DMCAs can be divided into two types. One type has a course parallel to that of the other branch of the DMCA, and the second type has a course that curves toward the temporal lobe. Only DMCAs with a sharply curved course to the temporal lobe were associated with aneurysms originating from the origin of this vessel.

The identification of anomalously early manifestations of the MCA is important for the surgical dissection of cerebral aneurysms associated with DMCAs. Because the DMCA may contribute to the normal cerebral blood supply, care should be taken not to damage this vessel during surgery. If the aneurysm

arises between the two M2 vessels originating at the carotid terminal site, the medial lenticulostriate perforators may be in close proximity and must be protected during dissection and clipping[10].

The DMCA may also play an important role in supplying collateral blood flow to the frontal lobe and basal ganglia through the perforating arteries[16]. However, it does not seem to supply significant flow to the main MCA territory. In cerebral infarction with stenosis or occlusion of only one branch of the DMCA, MR-angiography might appear similar to those produced by the normal condition, as in patient 3 in our study (Fig. 2). This MR-angiography image may be produced in one of two ways. First, the image may be the result of adequate collateral flow from the other branch of the DMCA, when there is stenosis or occlusion of one branch of the DMCA. The second possibility is that this image results from poor resolution on MR-angiography of the flow in the superior division of the DMCA. Under conditions of suspected cerebral infarction, we must consider this kind of MCA variation in interpreting the results of MR-angiography.

CONCLUSION

Type A DMCA has a course parallel to that of the other branch of the DMCA and a similar diameter, and can be regarded as an early bifurcation of the MCA. The type B DMCA that has a course parallel to that of the other branch of the DMCA may be regarded as an early bifurcation of the MCA. The type B DMCA with a temporal course can be regarded as an early temporal branch of the MCA. Although all DMCAs were found incidentally in this study, some clinical implications were found in literature review and in this study. Most DMCAs associated with aneurysms of the DMCA showed type B DMCAs with a temporal course. When cerebral infarction involving the MCA is suspected, we should consider this DMCA in interpreting MR-angiographic images.

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