Predicting Occluded Middle Cerebral Artery Morphology for Endovascular Mechanical Thrombectomy: A Contralateral Shape Analysis Approach

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Asian J Neurosurg 2024;19:435–438.

Abstract

Introduction Predicting the shape of the occluded middle cerebral artery (MCA) from the contralateral MCA might help catheterization in endovascular mechanical thrombectomy (EMT).

Materials and Methods We analyzed magnetic resonance (MR) angiography in 100 consecutive patients who had MR imaging for diseases other than acute ischemic stroke. To assess the symmetricity of MCA, the shape of M1, length of M1, number of M2, number of early branches (EBs), and distance from the top of the internal carotid artery to EB were investigated.

Results The shape of M1 was upward in 42%, horizontal in 47%, and downward in 11%. The M1 shape was the same on both sides in 64%, which exceeded the probability assumed to be left–right independent. The number of M2 trunks and EBs matched left and right in 86 and 55% of patients, respectively; however, these agreement rates were not higher than those with independent left and right sides. No left–right correlation was found between the M1 length and the distance from the internal carotid artery to EB.

Conclusion Based on our data, the symmetry of MCA was observed only in the shape of the M1 segment. This finding could be beneficial for EMT targeting MCA embolisms.

Keywords
- cerebral embolism
- endovascular mechanical thrombectomy
- middle cerebral artery
- MR angiography
- symmetry

article published online
June 24, 2024

DOI https://doi.org/10.1055/s-0044-1787869.
ISSN 2248-9614.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Introduction

In the treatment of acute ischemic stroke (AIS), endovascular mechanical thrombectomy (EMT) has been proven to be effective in improving the functional outcomes of patients with large vessel occlusion[1,2] and is widely used. However, EMT presents a risk for vessel wall perforation and dissection, which can result in serious complications. Due to blind manipulation, microcatheters may collide with or exert friction upon the vessel walls or the bifurcation site at an improper angle or force, increasing the risk of inadvertent perforations or dissections. The incidence rates of vessel wall perforation and dissection complicating EMT for AIS have been reported to be 0.9 and 1.7%, respectively.[1] Therefore, gentle and careful manipulation is required; however, the delay in recanalizing the occluded artery also leads to a worsened prognosis.[3]

The middle cerebral artery (MCA) is the most common target artery in EMT.[4] If the course of the occluded MCA can be predicted based on that of the contralateral MCA, this might help achieve a safer and more expeditious catheterization. Although a few studies have investigated the existence of bilateral MCA symmetry,[5] its usefulness in predicting the course of occluded MCA during EMT has not yet been determined. This study aims to conduct a retrospective analysis of the magnetic resonance angiography (MRA) images obtained at our hospital to assess the symmetry of the MCA to discuss its clinical application for EMT.

Materials and Methods

We conducted a study involving 100 consecutive cases of MRA obtained in October 2022 at our institution. We excluded cases with anomalous or occluded segments of the internal carotid artery (ICA)/A1/M1/M2, intracerebral space-occupying lesions (e.g., tumors, hemorrhages, or giant aneurysms), postcraniotomy cases, and cerebral arteriovenous malformation or moyamoya disease. The MRA images were obtained using the Ingenia Elition 3.0 T scanner (Philips, Amsterdam, Netherlands) with the following acquisition parameters: repetition time/echo time of 26/3.45 ms, flip angle of 18°, slice thickness of 1.1 mm, matrix of 360×512, field of view of 18×18 cm, and imaged area of 100 mm (across six slabs).

We assessed the factors, including age, sex, purpose of MR imaging (MRI), and the presence of atherosclerosis risk factors (i.e., hypertension, diabetes mellitus, and hyperglycemia). To analyze the morphological patterns of the MCA, we divided its morphology into five components: the shape of the M1 segment (upward/horizontal/downward), length of the M1 segment, number of M2 trunks, distance from the top of the ICA to early branches (EBs) such as the anterior temporal artery or orbitofrontal artery, and number of EBs. The shape and length of the M1 segment and distance to the first branch from M1 were evaluated based on the anterior–posterior (AP) images in which the basilar artery appears the longest. Regarding the classification of the shape of the M1 segment, we measured the distance (X) between the line connecting the midpoint of the proximal edge and the distal edge of M1 and the midpoint of M1 farthest from the previous. If X was 2 mm or longer, the shape of the M1 segment was defined as either upward or downward (►**Fig. 1A** and **B**). If X was less than 2 mm, it was defined as horizontal (►**Fig. 1C**). As for the M1 length, we defined it as the sum of distance "a" from the proximal edge to the flexion point and distance "b" from the flexion point to the distal edge (►**Fig. 1D**). Representative cases for each shape of M1 segment are shown in ►**Fig. 1E** and **F**. This study was

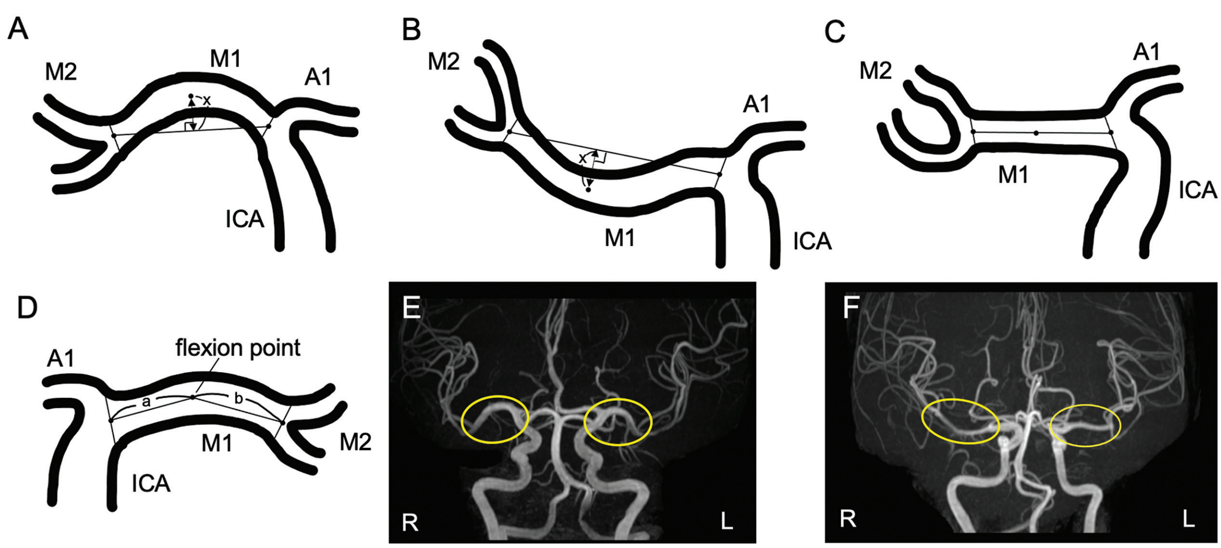

Fig. 1 (**A–C**) Classification of the shape of the M1 segment. X is the distance between the line connecting the midpoint of the proximal edge and the distal edge of M1 and the midpoint of M1 farthest from the line. If X is 2 mm or longer, the shape of the M1 segment is defined as upward (**A**) or downward (**B**). When X is less than 2 mm, it is classified as horizontal (**C**). The M1 length is defined as the sum of distance "a" from the proximal edge of M1 to the flexion point and distance "b" from the flexion point to the distal edge of M1 (**D**). Representative magnetic resonance (MR) images of the upward M1 on both sides (**E**), downward (**F**, right), and horizontal (**F**, left) M1. ICA, internal carotid artery.

approved by the institutional review board of our hospital (No. 2023–1).

Results

A total of 100 patients were included in this study. ►**Table 1** presents the patient's demographic information. The mean age was 66.6, with a standard deviation (SD) of 14.0. The reasons for the MRI scans included a follow-up observation of past history, such as unruptured cerebral aneurysm in 53 cases; symptom examination, such as that for dizziness and headache, in 33 cases; and health check examinations in 14 cases. The risk factors associated with atherosclerosis were hypertension in 52 cases, dyslipidemia in 42 cases, and diabetes in 18 cases.

►**Table 2** shows the ratio of each shape of the M1 segment, the number of M1/M2 bifurcations, and the number of EBs. As for the shape of the M1 segment, 84 arteries (42%) were upward, 94 arteries (47%) were horizontal, and 22 arteries (11%) were downward. The number of M2 trunks was two in 182 (91%), three in 16 (8%), and four in 2 patients (1%). Furthermore, the number of EBs was none in 101 (51%), one in 81 (41%), and two or more in 18 patients (9%). ►**Table 3** presents the nine groups based on the shape of the M1 segment on the left or right side. The left–right matching rate was 64% (64/100). If the M1 on the left or right side was upward, the probability of the opposite side upward was 70% (28/40) and 64% (28/44), respectively. For a horizontal shape on the left or right side, the probability of the opposite side being horizontal was 63% (33/52) and 79% (33/42), respectively. Similarly, the probability of the matching downward shape on the right and left sides were 38% (3/8) and 21% (3/14). These probabilities were higher than the original incidence (upward 42%, horizontal 47%, and downward 11%), indicating a potential similarity between the shape of the M1 segment on the left and right sides. No anomalies, such as accessory MCA or duplicated MCA, were observed among the 100 cases included in this study.

Table 1 Patient demographics ($n = 100$)

Factor	Value
Age, mean (SD), y	66.6 (14.0)
Sex, male	43
Reason for MRI	
Follow-up	53
Symptom examination	33
Health check examination	14
Atherosclerosis risk factor	
History of hypertension	52
History of dyslipidemia	42
History of diabetes mellitus	18

Abbreviations: MRI, magnetic resonance imaging; SD, standard deviation.

Table 2 Morphological pattern of middle cerebral artery ($n = 200$)

Patterns	*n* (%)
Shape of M1 segment	
Upward	84 (42)
Horizontal	94 (47)
Downward	22 (11)
Number of M2 trunks	
2	182 (91)
3	16 (8)
4	2 (1)
Number of early branches	
0	101 (51)
1	81(41)
2	18 (9)

Table 3 Shape of M1 segment

Lt \ Rt	Upward	Horizontal	Downward	Total
Upward	28	13	3	44
Horizontal	7	33	2	42
Downward	5	6	3	14
Total	40	52	8	100

Abbreviations: Lt, left; Rt, right.

The average M1 length was 17.2 mm ± SD 6.1 (3.2–44.0). No correlation was observed between the M1 lengths on the left and right sides ($r = 0.18$) (►**Supplementary Fig. S1**, available in the online version). The numbers of M2 trunks were 2 in 91% (182/200) and 3 or more in 9% (18/200) of all MCAs (►**Supplementary Table S1**, available in the online version). It matched on both sides in 86% of patients, indicating no symmetricity. The numbers of EBs were 0 in 50.5% (101/200), 1 in 40.5% (81/200), and 2 or more in 9% (18/200) of all MCAs (►**Supplementary Table S2**, available in the online version). It matched on both sides in 55% of patients; however, the agreement was not higher than with independent left and right sides, showing no obvious symmetry. The average distance to the EB was 9.47 mm ± SD 3.92. No correlation was observed between the distance to the EB on the left and right sides ($r = 0.12$) (►**Supplementary Fig. S2**, available in the online version).

Discussion

The occluded artery was invisible at the beginning of the EMT. Therefore, the cannulation of the occluded artery was performed blindly, perceiving a subtle resistance, which requires experience and poses a challenge for beginners to execute the procedure safely. Our findings suggest that the morphological pattern of the MCA is not entirely random; rather, a possible similarity in the shape of the M1 segment can be observed between the left and right sides. This information might be helpful to presume the course of invisible MCA and improve the safety of cannulation during EMT.

There have been some studies on predicting the course of occluded arteries. The utilization of fast imaging employing steady-state acquisition has been reported as effective in delineating the course of the occluded artery in cases of AIS.[6] However, reconstructing a three-dimensional image requires both time and expertise. Moreover, its accuracy diminishes when dealing with the proximity of the MCA to the brain parenchyma, especially in younger patients with less atrophic changes.[6] Although similar matching rates between left and right have been reported concerning the shape of M1 segment, the number of M2 trunks, and presence or absence of EBs in a previous study,[5] the present study suggests the shape of M1 segment is the most likely to match between left and right, and that the number of M2 trunks and EB do not match more frequently than their original incidence. We consider it crucial to understand the original frequency of each MCA characteristic when cannulating the occluded MCA.

Thrombectomy in AIS may be performed without MRA. However, our findings are still applicable even if computed tomography angiography is used. Moreover, the 2019 revision of the American Stroke Association/American Heart Association stroke guidelines also recommends the implementation of MRA as Class 1,[7] and many centers are applying MRA in response to this recommendation.

Limitations

This study has several limitations. First, a three-dimensional analysis of the shape and length of the M1 segment was not performed in this study. The visual appearance of the M1 segment was assessed based on the two-dimensional AP images obtained from MRA. Consequently, the shape and length of the M1 segment may differ from the real values of the original vessel. However, our primary focus was on the visual representation of M1 on a two-dimensional monitor during EMT, which is useful when catheter manipulation is conducted blindly. Second, the cohort consisted of individuals who underwent the procedure for reasons other than AIS. Therefore, our study's cohort might differ from that with an increased risk of cerebral embolism. Lastly, it is important to validate the applicability of our results to individuals who undergo mechanical thrombectomy. However, further research is needed to confirm the true generalizability of our results.

Conclusion

Our data showed that the shape of the M1 segment tended to coincide between the left and right sides. However, no correlation was observed in the length of the M1 segment, the number of M2 trunks, the number of EBs, and the distance from the top of the ICA to the EB between left and right. When cannulating the occluded MCA, it is appropriate to recognize the frequent patterns in the shape of the M1 segment and branching of M1. It is advisable to be aware of the common shapes of M1 characteristics rather than relying too heavily on the symmetry of the MCA between left and right.

Conflict of Interest
None declared.

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