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Original Article

Study of Anatomical Variations in Middle Cerebral Artery

R Jeyakumar[1], R Veerapandian[2]

[1]Senior Assistant Professor, Department of Neurosurgery, Madurai Medical College, Madurai, Tamil Nadu, India, [2]Professor, Department of Neurosurgery, Madurai Medical College, Madurai, Tamil Nadu, India

Abstract

Introduction: Middle cerebral artery (MCA) is the largest and most complex arterial system of the brain. An attempt has been made in this study to enhance our perception of the variations in the microvascular anatomy of MCA in our population.

Aim: The aim of the study was to study the variations in the microsurgical anatomy of the MCA in our population and to compare the variables with the studies on Western population and to discuss its importance with anatomic and surgical considerations.

Materials and Methods: A total of 15 fresh adult cadavers of both sexes were studied in the autopsy room in Madurai Medical College, Madurai, between June 2008 and January 2009. The different variables with regard to the MCA in our population were analyzed and compared with the studies in Western population as well as with other Indian studies.

Results: The mean length of the MCA in this study was 16.37 mm. It was also found to be shorter in length with bifurcating MCA and longer with trifurcating MCAs. The perforators were found to arise predominantly from the inferomedial aspect of the M1 segment. The branching pattern of MCA showed bifurcation in 73% and trifurcation in 27%.

Conclusion: MCA is larger of the two branches of internal carotid artery (ICA), and it is direct continuation with the ICA which favors any emboli to get lodged or secondaries to get deposited or abscess formation. Thorough knowledge of the microvascular anatomy and the myriads of variations are very essential for the operating surgeon to choose the ideal technique to avoid any catastrophe during and after surgery and to give the best possible functional outcome for the patients.

Key words: Digital subtraction angiography, Internal carotid artery, Middle cerebral artery

INTRODUCTION

The field of microsurgery has gone leaps and bounds over the years which help in better understanding of the normal anatomy and its intricate variations in the vascular and other minute structures in brain. Cadaveric microdissection is of immense help which forms the basis of our understanding of the intricate anatomy of the structures of the brain.

Vascular anatomy of the brain is fascinatingly complex of all the variations in the brain, but yet they are so conspicuous by their distinct anatomy and its unique features.

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The evolution of micro neurosurgery and the awareness of the arrangement of tiny perforating features vessels at the base of the brain have markedly and significantly improved the outcome and quality of the life of the patients subjected to surgery related to the vascular structures of the brain.

Middle cerebral artery (MCA) is the largest and most complex arterial system of the brain. Thorough knowledge of the microvascular anatomy and the myriads of variations are very essential for the operating surgeon to choose the ideal technique to avoid any catastrophe during and after surgery and to give the best possible functional outcome for the patients.

Various studies have been conducted in different sets of the population by various authors on MCA in an elaborate manner which includes a few studies on Indian population as well. With these various studies as guidelines, an attempt has been made in this study to enhance our perception of

Corresponding Author: Dr. R Jeyakumar, Department of Neurosurgery, Madurai Medical College, Madurai, Tamil Nadu, India. Phone: +91-9047069045. E-mail: jeyakumarraju@gmail.com

the variations in the microvascular anatomy of MCA in our population.

Aims and Objectives

The aim of the study was to study the variations in the microsurgical anatomy of the MCA in our population and to compare the variables with the studies on Western population and to discuss its importance with anatomic and surgical considerations.

MATERIALS AND METHODS

A total of 15 fresh adult cadavers of both sexes were studied in the autopsy room in Madurai Medical College, Madurai, between June 2008 and January 2009.

26 gauge needle, microscissors, 11 blade knife, bayonet forceps, fine-toothed forceps, poster color, cotton, and artery forceps were used for the dissection of the sylvian fissure.

×4 magnification using Heine magnifying Loupe was used for the dissection of the brain throughout the study.

8 megapixels Canon Ixus digital camera was used for taking the photographs.

Tabulation chart was used for entering the data and for further interpretation.

Procedure

During postmortem examination of the cadavers after the skull vault was removed taking special care not to injure the dura. The dura was opened from the frontal base in a transverse direction, and after cutting the falx, the frontal lobes were retracted slowly, and the optic nerves were exposed and carefully cut along with the internal carotid artery (ICA) at their entrance into the cranial cavity. Both the cerebral hemispheres were lifted carefully after dividing the cranial nerves one by one.

At the level of the tentorial hiatus, the brain stem along with the basilar artery was cut, and entire cerebral hemispheres delivered, after dividing the posterior attachment of falx. The specimen was soaked for 10–15 min in 10% formaldehyde solution.

Further dissections were carried out using a magnifying loupe with ×4 magnification. The sylvian fissure was opened with 26 gauge needle below the sylvian vein, and the dissection was extended with bayonet forceps.

The bifurcation of ICA is traced, and then MCA was traced with its branches coursing over the insula, the opercular and cortical branches were further dissected. The origin of the ICA is ligated with a silk, and red poster color solution was injected to make the vessels and perforators prominent and for ease of dissection.

The MI segment of MCA was carefully dissected, and the early branches from the superior aspect and the perforators from the inferior aspect were exposed.

The distribution of perforators along the MCA and their number were noted.

The branching pattern of MCA into different trunks was noted.

The division of the trunks into stem arteries and their further course over the insular region, opercular region, and cortical region was noted by further dissection.

The distribution of the cortical branches was noted.

The entire architecture of the MCA and its branches were photographed.

Observations

The following observations were made

1. Length of the MCA (M1 segment)
2. Early branches from the MCA
3. Perforators from.
   a. M1 segment.
      - Proximal
      - Distal.
   b. M2 segment.
4. Branching pattern of MCA into
   a. Bifurcation
   b. Trifurcation
   c. Multiple branches.

RESULTS AND ANALYSIS

The recorded data were analyzed with descriptive statistics and student *t*-test.

M1 Segment Length (M1SL) [Table 1]

The average length of M1 segment was:

- Longest M1 was 24 mm
- Shortest M1 was 12 mm.

M1 Length in Variously Dividing MCA [Table 2]

- The average length of M1 in bifurcating cases: 15.32 mm
- The average length of M1 in trifurcating cases: 19.25 mm.

The differences in M1SL in variously dividing MCA were found to be statistically significant using the student *t*-test.

Early Branches [Table 3]

The arteries supplying the cortical areas which take their origin directly from M1 segment of MCA are called early branches.

It varies from 1 to 3 in each hemisphere.

33.33% had 1 early branch.

- 46.6% had 2 early branches
- 20.0% had 3 early branches.

In this study, where there were more than 2 early branches; one of the vessels supplied the frontal lobe by replacing the orbitofrontal artery.

Accessory MCA

Accessory MCA is arteries arising from ICA, anterior cerebral artery (ACA), or AcomA which traverse through the sylvian fissure to supply the cortical areas.

- In this study, there was no accessory MCA.

Perforating Arteries [Tables 4 and 5]

Perforators are small twigs of blood vessels that arise from major arteries such as ICA, ACA, AcomA, and MCA. The majority of perforators of the MCA were from the inferomedial surface, and they divide in a candelabra pattern before entering the anterior perforated substance.

- Average number of perforators from proximal half of MCA is 7.07.
- Average number of perforators from distal half of MCA is 2.
- The MCA was divided into two groups as short MCA and long MCA taking into consideration 16 mm as the arbitrary cut off point.

Short MCA

- Proximal perforators contribute to 6.27
- Distal perforators contribute to 2.91.

Long MCA

- Proximal perforators contribute to 7.53
- Distal perforators contribute to 2.74.

There was no significant difference in the distribution of perforators in both long and short MCAs.

M2 segment of the MCA also contributed to as few perforators.

No significant contribution of perforators from the frontal and temporal cortical branches as it is reported in other studies.

Division of MCA [Table 6]

- MCA - bifurcated into superior and inferior trunk in 22 cases (73.3%).
- On the right side 12 trifurcations were noted, and on the left side, 10 trifurcations were noted.
- MCA - trifurcated into superior, middle, and inferior trunks in 8 cases (26.6%).
- On the right side 5 trifurcated and on the left side 3 trifurcated.
- There were no multiple divisions of MCA in this study.

With regard to the pattern of division between two sides, there was symmetry in most cases.

Table 1: M1SL

Part of MCA	*n*	Minimum	Maximum	Mean±SD
M1SL	30	12 mm	24 mm	16.37 mm±2.974

M1SL: M1 segment length, SD: Standard deviation

Table 2: M1 length in variously dividing MC

Divisions	*n*	Minimum	Maximum	Mean±SD
Bifurcation	22	12	18	15.32±2.033
Trifurcation	8	14	24	19.25±3.327
Total	30			

SD: Standard deviation

Table 3: Early branches

No	Frequency (%)
1	10 (33.33)
2	14 (46.6)
3	6 (20.00)

Table 4: Perforators

Perforators	*n*	Minimum	Maximum	Mean±SD
M1PP	30	4	13	7.07±1.88
M1DP	30	0	6	2.8±1.24

SD: Standard deviation

Table 5: MCA length versus perforators

MCA	Proximal perforators	Distal perforators
Short MCA		
n	11	11
Min	5	1
Max	9	5
Mean	6.27	2.91
SD	1.35	1.14
Long MCA		
n	19	19
Min	4	0
Max	13	6
Mean	7.53	2.74
SD	2.00	1.33

MCA: Middle cerebral artery, SD: Standard deviation

Side versus Division Cross Tabulation [Table 7]

Only in 2 cases the MCA bifurcated on the right side and trifurcated on the left side.

There were no cases wherein the MCA divided into multiple branches in this sample.

Largest of Cortical Arteries [Table 8]

Either of an angular artery or temporal occipital artery was the largest cortical artery (LCA) in this sample, or there were instances where both compensated when either of these arteries was absent.

- The angular artery was the LCA in 53.4% of cases.
- The temporal occipital artery was the LCA in 46.6% of cases.

When compared with the western studies the MCA1 length was longer by a few mm, but it was longer in another Indian study [Figure 1]

Present study	-	16.37
Rhoton	-	15
Umansky	-	15.1
Yasargil	-	15
Balaji	-	20

Early Branches to Frontal Lobe [Figure 2]

The early branch to the frontal lobe was 20% which is higher than the incidence reported by Rhoton (10%) and lower than the incidence published by Balaji Pai who has reported an (30%) incidence.

Table 6: Division of MCA

Type of division	Frequency (%)
Bifurcation	22 (73.3)
Trifurcation	8 (26.6)
Multiple	0 (0)
Total	30 (99.9)

MCA: Middle cerebral artery

Table 7: Side versus division cross tabulation

Side	Division			Total
	Bifurcation	Trifurcation	Multiple	
Right	12	5	0	17
Left	10	3	0	13
Total	22	8	0	30

Table 8: Largest of cortical arteries

Type of cortical artery	Frequency (%)
LCA	16 (53.4)
LCTO	14 (46.6)

LCA: Largest cortical artery, LCTO: Largest cortical temporo occipital

Accessory MCA

There were no cases which have an accessory MCA whereas Yasargil has recorded an incidence of 2.9%.

Branching Pattern of MCA [Figure 3]

Rhoton	-	78% (Bifurcated)
	-	12% (Trifurcated)
	-	10% (Multiple)
Present Study	-	73% (Bifurcated)
	-	27% (Trifurcated)
Yasargil	-	77% (Bifurcated)
	-	13% (Trifurcated)
	-	10% (Multiple)
Balaji	-	80% (Bifurcated)
	-	20% (Trifurcated)
	-	10% (Multiple)

Perforators of M1 Segment [Figure 4]

The average number of M1 segment perforators in this study was compared with the other study by Rhoton.

- The average number of perforator in study by Rhoton study - 10
- The average number of perforator in this study - 9.2.

DISCUSSION

The different variables with regard to the MCA in our in population were analyzed and compared with the studies

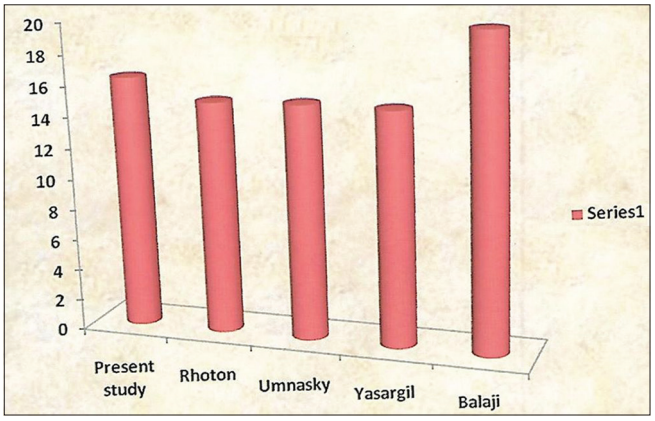

Figure 1: Middle cerebral artery length

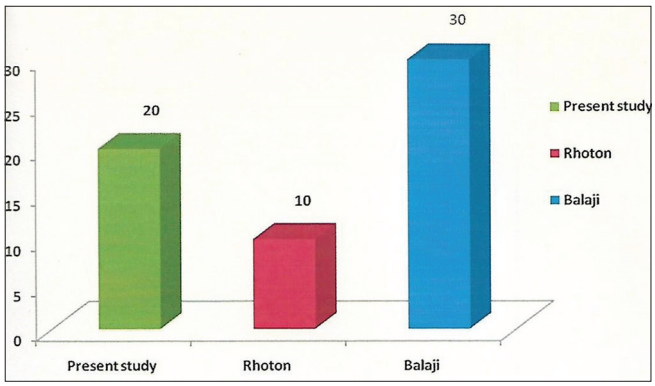

Figure 2: Early branches to frontal lobe

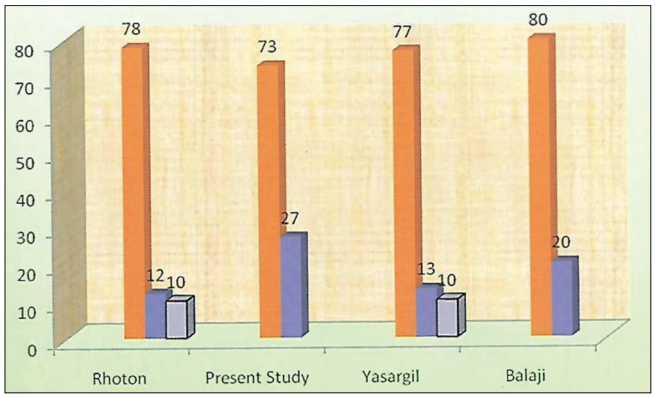

Figure 3: Branching pattern of middle cerebral artery

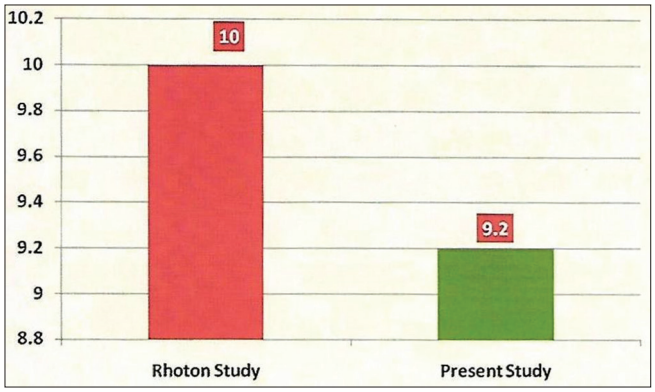

Figure 4: Average perforators of the M1 segment

in Western population as well as with another Indian study with respect to the anatomical perspectives and surgical considerations.

1. MCA is the largest branch of the ICA, and it is in direct continuation with the ICA whereas the ACA forms an angle with that of ICA.
2. The mean length of the MCA in this study was 16.37 mm. It was also found to be shorter in length in cases with bifurcating MCA and longer in length in cases with trifurcating MCAs. This was also found to be shorter in length in cases with bifurcating MCA. This has been compared with the western studies which showed a slightly shorter MCA compared with this study sample.
3. Early branches were noted in all cases in this study, and they were either single, two and two branches and in the last category which constituted 20% in this study one of the branches supplied the frontal lobe. This was compared with few, studies where Rhoton reported 10% incidence of frontal lobe supply and Pai *et al.* reported 30% incidence.[1-3, 10]
4. The incidence of accessory MCA though reported in different studies it was not found in this study sample.[12]
5. The perforators from the MCA were found to arise predominantly from the inferomedial aspect with a uniform distribution throughout the length of the M1 segment. They entered the anterior perforated substance as described by the other studies. The average number of perforators distributed both in the proximal and distal segment was similar to other studies done in the Western population.
6. The branching pattern of MCA showed bifurcation in 73% and trifurcation in 27%. In the majority of the cases, there was symmetry in the division of the MCA between the two sides, but a few cases showed the difference between the two sides.
7. Similar to the way the MCA originates from 1CA the dominant trunk of MCA is more in line with that of parent vessel and the nondominant trunk offshoots from the MCA at an angle.
8. The angular or temporo-occipital artery was the largest of the cortical arteries observed.
    - Embolic stroke, (the most common cause of stoke) and secondary deposits tend to affects the MCA territory as it is more parallel and in line with the MCA and comparatively larger in caliber and cross section.[5,7]
    - Involvement of the individual cortical branch may produce symptoms pertaining to the area supplied by that branch due to the variations in size and area of the cortex supplied it is difficult to identify the exact branch it is difficult to identify the block in these vessels even with angiography.

Surgical Consideration

- The MCA is mostly uniform in size than the gross variation in size of its counterpart the ACA poses a difficult in locating the division preoperatively. A detailed angiographic evaluation before surgery is mandatory.
- Irrespective of the adequate length of MCA it is not freely mobile, and mobility is being restricted by the perforators.[9]
- During aneurysm surgery, the early branches from the super lateral aspect should be preserved as they supply the cortical areas replacing the cortical branches.[4]
- Even though few perforators can arise from the accessory MCA they do not predominate in supply to any cortical area, hence, they can dispensed during surgery safely of at all needed.
- During surgery in and around MCA, the dissection is kept to a bare minimum in the inferomedial aspect since the likelihood of injury to the perforators is more in the event of doing so.[6,11,15]
- In aneurysm surgery of MCA, the application of temporary clips should be as distal as possible to minimize the injury to the perforators as for as possible.
- The perforators in the insula are dealt with care to avoid injury since it may cause limb weakness due to corona

radiata and internal capsule involvement as a result of perforator injury.[8] Hence, extreme care should be taken to prevent the mobilization of these vessels.
- In case of MCA occlusion, the most preferred vessel for STMC bypass is an angular artery or temporal occipital artery.[14]

CONCLUSION

MCA is larger of the two branches of ICA, and it is direct continuation with the ICA which favors any emboli to get lodged there resulting in a stroke of that territory or secondaries to get deposited or abscess formation in that territory. The length of M1 segment is shorter in the bifurcating MCA and longer in trifurcating MCA. The mobility of the M2 segment is hampered by the interomedial perforators of the M1 segment. Accessory MCA or duplication of MCA is a rare phenomenon, and they do not have specific cortical supply, hence they can be sacrificed if necessary.[13] There is uniform distribution or perforators from the inferomedial aspect of MCA, hence, dissection in that area should be minimal to avoid injury. During aneurysm surgery, the application of temporary clips should be distal as possible to avoid injury to the perforators. The branching pattern of the MCA should be elucidated with pre-operative catheter angiogram or DSA since it is the common site of aneurysm.

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