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Original Research Article

STUDY OF M1 SEGMENT OF MIDDLE CEREBRAL ARTERY IN HUMAN CADAVERIC BRAINS WITH CLINICAL IMPLICATIONS OF ITS EARLY BRANCHES

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ABSTRACT

Background: Human brain gets its nutrition from carotido and vertebro-basilar system of vessels. MCA, being the larger terminal branch of ICA supplies the cortical areas of brain concerned with speech and language. It is the most commonly involved artery in cerebro-vascular accidents as in stroke which is characterised by sudden onset of focal neurological deficit. The anatomical study is of utmost important to neurovascular surgeons.

Materials and methods: The present study was undertaken in 140 cadaveric human brain hemispheres of 70 formalin fixed brains from Department of Anatomy and Forensic medicine of Mysore medical college and ESIC MC and PGIMSR, Bangalore. Fixed brains were sagitally bisected into right and left halves by brain cutting knife. Meninges were cleared and MCA was identified which was the larger and direct branch of ICA. Measurements of ICA and MCA was taken using thread and measuring scale. LSAs arising from MI segment MCA were counted using hand lens. Any early branch if present was noted. Angle was noted between M1 and M2 segment. Presence of any anomalies were studied

Results: The mean of length of M1 was found slightly more on the left side (2.09 cms) in comparison to right side (1.90 cms). The mean diameter of M1 segment of MCA was more on the left side (0.352 cms), in comparison to right side (0.317 cms). The mean diameter of left MCA (0.352 cms) and left ICA (0.359 cms) were of the same size. The mean diameter of right MCA (0.317 cms) and right ICA (0.323 cms) were almost of the same size. The number of LSAs were more on left side (5.9) in comparison to right side (5.67). Early branches were found to be more on right side (5) than left side (3). The angle was observed to be acute in all specimens.

Conclusion: This study was undertaken due to its clinical significance to stroke. Observations made on MCA revealed greater length of MCA carrying greater proportion of blood flow to the left side – a feature which supports the concept of vascular asymmetry. The knowledge of early branch arising from proximal segment of MCA is helpful for neurovascular surgeons to make a fairer decision in planning the treatment for any neurovscular disorders. The authors felt the necessity of documentation of data inferred by our study as there are very few articles on MCA found published in Indian literature.

KEY WORDS: M1 Segment Of Middle Cerebral Artery, Lenticulostriate Branches, Early Branch, Stroke, Vascular Anomalies, Neurovascular Surgeons.

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INTRODUCTION

Brain is uninterupedly supplied by carotid-vertebral system of vessels. MCA, being the larger branch of ICA is divided into 4 segments.

M1 segment (sphenoidal) -from the termination of the internal carotid artery to the bi/trifurcation

M2 segment (insular) – the segment running in lateral fissure

M3 segment (opercular) – coming out of lateral fissure.

M4 segment – cortical portions [1].

The shenoidal segment terminates at the site of a 90 degree turn (genu) [2]. [Figure-1] The left MCA has a longer column of flow of blood reaching directly from arch of aorta, as a result of which the emboli from ICA go frequently to MCA than to ACA resulting in cerebrovascular accidents.

Lenticulostriate (LSAs) arteries are central branches that arise at its origin and enter the anterior perforated substance supplies basal ganglia. The lateral striate branch is known as Charcot's artery of cerebral haemorrhage. Care should be taken not to damage these LSA's during cerebro vascular surgeries, or it may result in severe and irreversible neurological defecit. The origin of LSAs is very much debated. Hence an attempt has been made in the present study to provide more information on this aspect.

The early branches are those cortical branches arising from main trunk (M1 segment) after lenticulostriate arteries and before it bifurcates or trifurcates [3].

Morphology of MCA is clinically important because of its high prevalence in cerebrovascular accidents. It is the second most common location for intracranial aneurysms after anterior communicating artery [3]. Aneurysms arising from MCA ranges from 20-45%.[4]. With introduction of interventional stroke treatment, knowledge of MCA becomes even more important as it is the most common location of clot available treatment by mechanical thrombectomy [5].

MCA is phylogenetically the youngest intracranial artery. Its evolution is related to development of lobes of cerebrum. Cortical vessels which will form MCA appear on lateral aspects of hemispheres before infolding and deepening of hemispheres occurs, leading to formation of insula. Between 8-12 weeks gestation, these cortical vessels originate directly from terminal segment of ICA. When insula develops, the arteries penetrate the forming sylvian fissure. Also in this period, they form MCA which continues to develop upto birth[6]. Considering the frequent incidence of vascular pathologies in MCA, knowledge on its course and anatomical type is crucial for effects of intra vascular and neurosurgical procedures [7].

The aim of this cadaveric study is to observe the anatomy and anomalies of M1 segment of middle cerebral arteries in South Indian population

MATERIALS AND METHODS

The present study was undertaken in 140 cadaveric human brain hemispheres of 70 formalin fixed brains from Department of Anatomy and Forensic medicine of Mysore medical college and ESIC MC and PGIMSR, Bangalore.

Fixed brains were sagitally bisected into right and left halves by brain cutting knife. Meninges were cleared and MCA was identified which was the larger and direct branch of ICA.

M1 segment was studied from its origin from ICA upto its division in the insula, Length of M1 segment was measured from its origin from ICA to its bifurcation at the insula by placing the thread along the course of the artery, in M1 segment of MCA . The length of the thread was measured by using scale.

The external diameter of the artery was measured using the divider, and the distance between two points of divider was measured using a scale.

LSAs arising from MI segment MCA were counted using hand lens near anterior perforated substance.

Any early branch if present was noted. Its course was studied on both the sides and the area of its supply.

The bend or the angle where M1 bends and enters the sylvian fissure was observed known as knee

Statistical tool used – paired 't' test was used to analyse the observation

The Paired-Samples T Test procedure compares

the means of two variables for a single group. It computes the differences between values of the two variables for each case and tests whether the average differs from 0.

All the statistical calculations were done through SPSS (Statistical Presentation System Software) for Windows Version 14.0 Evaluation version (SPSS, 2005. SPSS Inc, New York).

RESULTS

The mean of length of M1 was found slightly more on the left side (2.09 cms) in comparison to right side (1.90 cms). [Table-1]

The mean diameter of M1 segment of MCA was more on the left side (0.352 cm), in comparison to right side (0.317 cm). [Table-2 and Graph-1]

The mean diameter of right and left ICA were (0.323 cm) and (0.359 cm) respectively. [Tab-3]

The mean diameter of left MCA (0.352 cm) and left ICA (0.359 cm) were of the same size. [Table-4 and Graph-2]

The mean diameter of right MCA (0.317 cm) and right ICA (0.323 cm) were almost of the same size. [Table-4 and Graph-2]

The number of LSAs were more on left side (5.9) in comparison to right side (5.67). [Graph-3] [Figure-2 and Figure-3]

In one specimen, LSAs arose at the aneurysm point [Figure-4]

LSAs arose at the point of bifurcation in one specimen [Figure-5] and from early branch from another specimen [Figure-6]

Early branches were found to be more on right side (5) than left side (3). Early branches to frontal area (EFB's) was more than early branches to temporal region ETB's) [Figur-7 and Figure-8]

Angle between m1 and m2 segments (knee)

The knee was observed to be acute in all specimens [Figure-1]

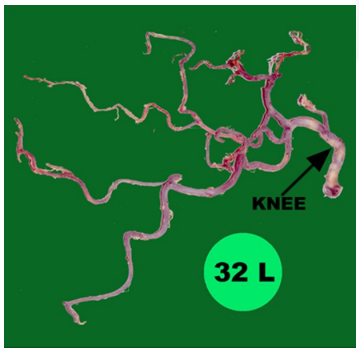


Fig. 1: Angle between M1 and M2 segments.

Fig. 2: Lenticulostriate branches,

Fig. 3: Lenticulostriate arteries(LSAs).

Fig. 4: Lenticulostriate arteries (LSA's) arising at aneurysm point.

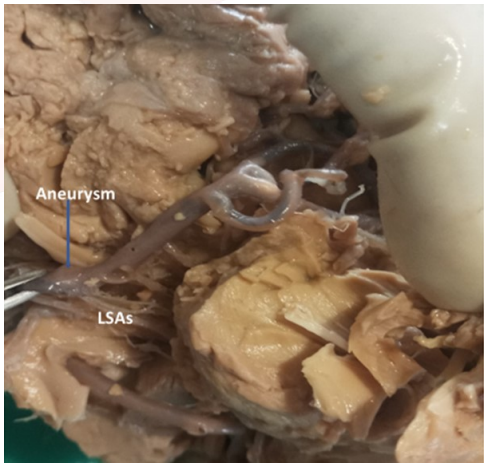


Fig. 5: Lenticulostriate arteries (LSA's) arising at point of bifurcation.

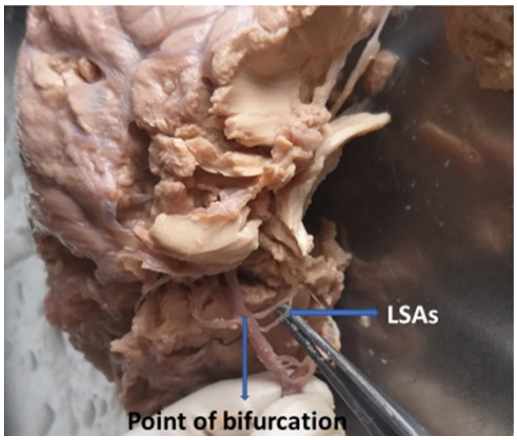


Fig. 6: Lenticulostriate arteries (LSA's) arising from early branch.

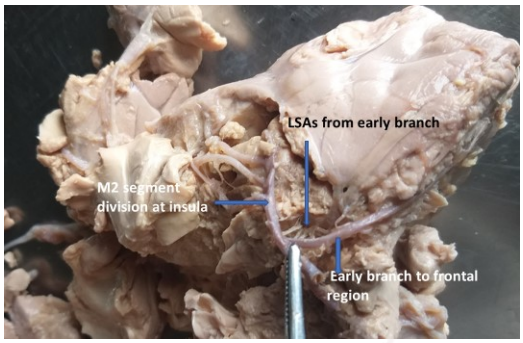


Fig. 7: Early branch to frontal region.

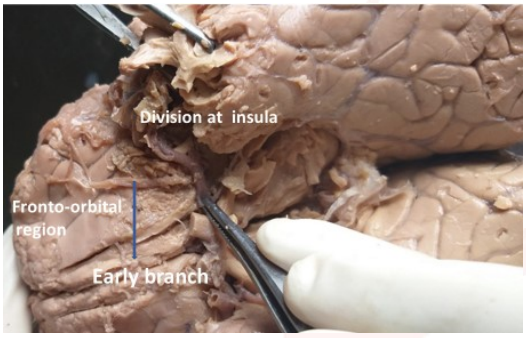


Fig. 8: Showing the Early Branch.

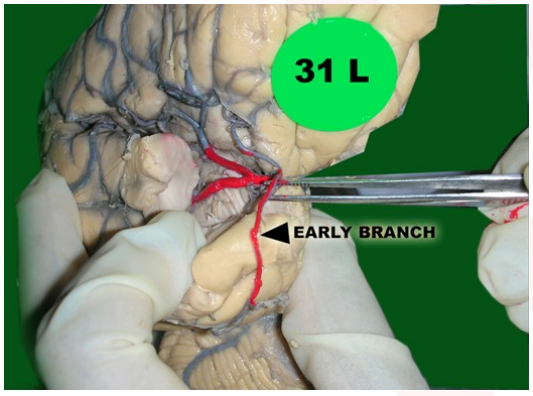


Table 1: Length in cms of M1 segment of MCA of Right and Left side.

	Right	Left
Min	1.1	1.3
Max	2.8	3.2
Mean	1.908571	2.09
SD	0.360251	0.38754

Right vs. Left of mean length
Paired 't' test = -5.888
$p < 0.000$ (Highly significant)

Table 2: Diameter in cms of M1 segment of MCA of Right and Left side.

	Right	Left
Min	0.2	0.2
Max	0.5	0.5
Mean	0.31786	0.35286
SD	0.06021	0.07366

Right vs. Left of mean diameter
Paired 't' test = -3.417;
$p < 0.001$ (Highly significant)

Graph 1: Mean Diameter in cms of M1 segment of MCA of Right and Left side

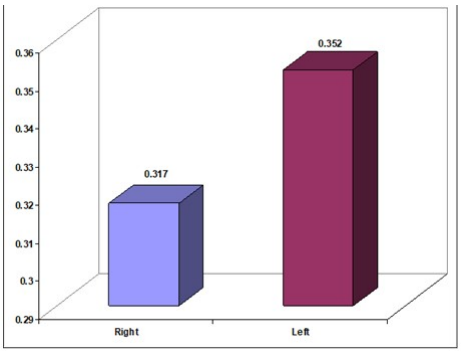


Table 3: Diameter of ICA at its bifurcation (in cm)

Min.	0.2	0.2
Max.	0.5	0.6
Mean.	0.323571429	0.359285714
SD	0.061809331	0.075801446

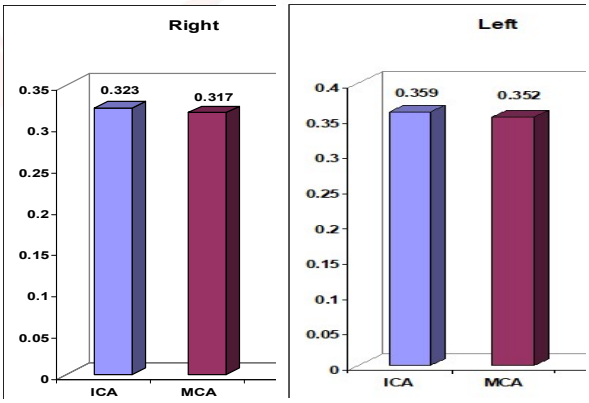
Right vs. Left of mean diameter, Paired 't' test = -3.997;
$p < 0.000$ (Highly significant)

Table 4: Comparison of mean diameters of ICA and MCA.

	Right	Left
ICA	0.323	0.359
MCA	0.317	0.352

Right ICA and Right MCA : $p < 0.569$ (Not significant)
Left ICA and Left MCA : $p < 0.643$ (Not significant)

Graph 2: Comparison of mean diameters of ICA, MCA.



Graph 3: Mean value of Lenticulostriate arteries (LSA's).

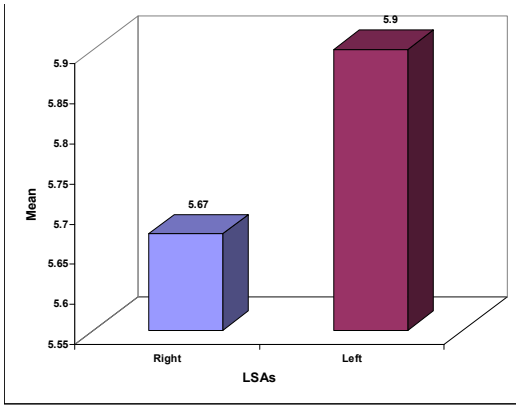


Table 5: Early Branches.

	Right	Left	Total	Percentage
Number of specimens	5	3	8	5.71

Table 6: Comparison of length of MCA from previous studies.

Sl.no	Author	Year	Method of study	Number of specimens	Right	Left
1	Jain [22]	1964		610	Mean of 1.6 cms (0.5-3 cms)	
2	Gibo H et al [11]	1981	Micro-anatomical	54	Mean of 9.4 mm(4.3-19.5mm)	
3	Umansky F et al [15]	1984	Micro-anatomical	70	Mean of 15.35 mm	
4	Ciszek B et al[37]	1993	Micro-anatomical		Mean of 17.7 mm	
5	Idowu OE et al[2]	2002	Micro-anatomical		Mean of 15.43 mm	
6	Tanriover N et al23]	2003	Micro-anatomical		Mean of 17.82 mm	
7	S.B Pai [12]	2005	Microscopic dissection	5	Mean of 20 mm	
8	Eugeniuz [38]	2007		114	6.76+-4.25mm	6.48+-4.27mm
9	Anna [39]	2010	CT angiogram	115	15.62 mms	Little longer
10	S. Sundari [14]	2015			Mean of 14-16mms	
11	Pawel [3]	2017			Mean of 15.8 mms	
12	Present study		Dissection	140	1.9 cms(19.0 mm)	2.09 cms (20.9 mm)

Table 7: Comparison of diameters of MCA from previous studies.

Sl.no	Author	Year	Method of study	Number of specimens	Right	Left
1	Jain [22]	1964		610	0.3 – 0.5 cms	
2	Gibo H et al	1981	Micro- anatomical	54	Mean of 3.9 mm	
3	Umansky F et al	1984	Micro- anatomical	70	3.0+- 1.3 mm	
4	Krabie-Hartkamp M J et al [40]	1998	MRA		2.3- 2.8 mm	
5	Idowu OE et al	2002	Micro- anatomical		Mean of 3.49 mm	
6	Tanriover N et al	2003	Micro- anatomical		Mean of 3.71 mm	
7	Yang H et al[41]	2003	Anatomical/DSA		2.93+- 1.44 mm	
8	Pacholec E et al [42]	2003	MRA		1.96- 2.6 mms	
9	S.B Pai	2005	Microscopic dissection	5	Mean of 3.35 mm	
10	Zurada A	2010	CTA		Mean of 2.23 mm	
10	Eugeniuz	2007	DSA and MRA	114	2.38+-0.9 mm	
11	S. Sundari[4]	2015			Mean of 3-6 mms	
12	Present study		Dissection	140	0.31 cms	0.35 cms

Table 8: Comparison of incidence of early branch from m1 segment of MCA from previous studies.

Sl.no	Author	Year	Method of study	Number of specimens	EFB	ETB
1	Gibo H et al	1981			5 cases (10%)	17 cases (34%)
2	Ogeng'o et al				104 cases (36.1%)	184 cases (63.9%)
3	Rhoton [43]				Only one early branch	
4	Ciszek et al				EFB positioned between 2 ETB	
5	Teal et al				3 cases	
6	Tanriover	2003	Anatomical and angiograms	50 hemisheres	32% hemispheres	
7	Chang Sub Lee et al[45]	2011	Angiogram	78 hemispheres	74.4%(58)	
8	Present study			140 hemispheres	5-right 3-left	

DISCUSSION

The Anatomy of MCA in relation to occlusion of its branches was described in detail by Foix and Levy in 1927 just prior to introduction of cerebral angiography [8]. Earlier studies on MCA are examined by angiographic methods [9]. Stenosed middle cerebral artery was demonstrated within 2 cms of M1 segment by Cerebral angiography [10]. The branches of MCA demonstrates vascular asymmetry in terms of length, size and proportion of blood flow. The left MCA is more prone for vascular haemorrhages since the blood flows in it at higher pressure. Earlier studies of MCA are examined by angiography, MRI, or by injection techniques. In our study, it is based on the dissection method done very meticulously.

Our study correlates with the earlier studies of Gibo [11] and Pai [12], while other studies showed shorter length. [Table-6]. The length was measured in cms in our study. Grellier et al [13] mentioned that the main trunk is classified as short (3-12 mm), medium (13-22 mm) and long (23-40 mm). Pawel [2] defined short M1 segment as shorter than 10mm. Our study showed 19.08 mm which belongs to medium length according to Grellier. Variations in the length is clinically important as the flow will be more in the shorter arteries and may be prone for damage to the tunics of arteries. But in longer arteries, flow is sluggish which is a predisposing factor for formation of thrombus [14]. The total length of the vessel is directly proportional to the total amount of blood flow in it. In the present study, the greater length of MCA observed on the left side perhaps is to supply greater amount of blood to the left cerebral hemisphere. Whether the selective greater quantity of blood flow to the left hemisphere observed in the present investigation can be attributed to side dominance is worth thinking.

The study of diameter of ICA was correlating with the results of Umansky [15] in 1984 which was 3.0+- 1.3 mm. Our study on diameter of MCA was compared with the previous studies (Table-7). The diameter of ICA and MCA was observed to be almost the same. Hypothesis states that flow changes are due to altered resistance caused by diameter changes within the small vessels distal to M1 segment of MCA and that the large vessels mainly serve as conductance of channels [16]. Hiroki Hongo studied the outer diameter of atherosclerotic MCA in two group of patients and found the ratio of stenotic side to normal side was smaller in variant group than in wild group [17].

Lenticulostriate arteries (LSA'S) are collection of small perforating arteries that supply basal ganglia. These arteries were divided as medial -those arising from proximal part of M1 segment and lateral- those arising from distal part of M1segment [18]. Previous studies have shown the origin of LSA s at different sites. The site of origin of distal striate (Charcot's artery) branches was studied in 600 MCA and found that LSA s was originating from MCA in 51.1%, originated at point of division of MCA IN 25.6%, and in 20.3% ,it arose from one of the terminal branches of MCA [19]. The Charcot's artery of cerebral haemorrhage which is a lenticulostriate branch is the usual culprit [20]. The perforating branches arose from secondary trunks when the division occurs more proximal. During surgical procedures, the surgeons should be careful to find the perforating branches from secondary trunks which takes a recurrent course and enter anterior perforated substance [15]. The major perforating vessels arose from one of the division of MCA [21]. The perforating arteries originated from main trunk in 79.6% and in 20.3%, they arose after division [22]. LSA's arose from 81% of EFBs and from 48% of ETBs [23].

The number of lenticulostriate branches was more on left side when compared to right side. LSAs arose at the point of division in one specimen [Figure-5] as described by Ronald, and from early branch in another specimen [Figure-6]. Due to variations in origin of LSA s, the vascular surgeons should be aware of various origins and avoid injury to the arteries during surgeries in these regions. The lenticulostriate branches which supply the corpus striatum were also counted using hand lens and their number was found to be insignificantly more on the left side. Lenticulostriate arteries (LSA'S) are involved in many neurological disorders like ischaemic and haemorrhagic cerebral strokes. The visualisation of LSA's using 7.0T MR angiography, is possible in vivo human studies

noninvasively and study the early changes of cerebral strokes [24]. At surgery, it is necessary to produce the working space by dissecting sylvian fissure sufficiently and to prevent ischaemic complication by avoiding injury to LSA [25]. LSAs (perforating) arteries was examined in vascular casts of 48 MCA and 32 CT scan and arranged between 2-12, and classified the origin to be either from main trunk, terminal trunk, Bifurcation trunk or arising separately or from common trunk [26]. Our study showed mean of LSA s of left side was 5.9 in comparison with right side was 5.67. Our study was compared with the previous studies in1985 , where LSAs in each hemispheres varied from 5-29 [27].

If a cortical branch originates prior to the initial branching, the artery is referred to as an early branch [28]. Early branches can be divided into early frontal branches (EFB) or early temporal branch (ETB) [29]. If branching occurs within 5 mm from the MCA origin, it is referred to as early branching [30]. Early branching has also been defined as branching within the proximal half of the M1 segment [31]. These branches run to temporal lobe (77%) and to frontal lobe (23%) [27]. Four configuration are defined as 1.No early branches, 2.Only EFB, 3.Only ETB and 4.Early frontal and early temporal branches [32].

Our study belonged to configuration 4, with predominance to temporal region. Early branches were found to be more on right side (5) than left side (3). Early branches to frontal area (EFB's) was less than early branches to temporal region ETB's). The over all incidence of early branch was 11.4% in our study. So far in the previous literatures, only 2.7% to 11.3% of early branching have been reported. In the present study, a small percentage (11.4%) of early branches were observed arising from the proximal part of M1 segment of MCA. These branches selectively supplied temporal lobe and the adjoining area. The number of vessels were slightly more on the right side than on the left side. These early branches are probably meant for supplying important functional area located in this area. This feature is in agreement to the similar observations made by Gibo H et al [11]. Comparison with previous others were made with respect to early branch and its aneurysm. [Table- 8]. Early branch aneurysms were more common than M1 segment bifurcation aneurysms [33]. Aneurysms amounts to 3.4% that arise from early branch and LSAs [3].

Endovascular treatment for early branch aneurysms is feasible and safe [34].

The M1 segment of MCA continues as M2 segment in the mouth of the Sylvian fissure at an acute angle in almost all the specimens. Whether this constant feature observed is a mechanical adaptation for providing the dampening effect to the blood flow is worth speculating.

Although the MCA anomalies are less frequent, three types are documented in previous literature [2,3,11,35]. They include fenestration, a duplicated MCA (from ICA) and an accessory MCA (from ACA).These extra vessels may play a role in collateral circulation in case of arterial blocks. These blocks may leads to stroke. In these cases, the signs of stroke can be confusing, if the anatomical knowledge is not properly understood. But our study had no anomalies except for the aneurysm which we have documented in our earlier study. Further study in this regard has to be done in future.

In post-term pregnancies, the proximal MCA pulsatality index significantly predicts umbilical artery po2 at delivery but does not predict p^H [36].

CONCLUSION

Studies made on MCA revealed greater length of the vessel on the left side carrying greater amount of blood flow. This appears to be a supportive feature for the vascular asymmetry of the carotid system of blood flow and left side dominance of the cerebral hemisphere. The diameter of ICA and MCA were of equal size which establishes a principle of greater flow of blood through the larger MCA branch of ICA.

The lenticulostriate branches were more in number on the left side, a feature which falls in line with the concept of greater amount of blood flow to the left side of brain. Early branches are probably meant for supplying important functional areas of temporal and frontal lobe.

Acute angle observed at the junction of M1 and M2 segments of MCA is perhaps a mechanical

adaptation to provide dampening effect to its blood flow. The low percentage of aneurysm indicates less danger posed to MCA and its neighbouring structures.

Our study provides morphometric analysis of MCA which may help neurovascular surgeons to plan the operative procedure for patients with intracranial pathology involving M1 segment.

Anatomical knowledge of early branch with respect to its aneurysms shows clinical relevance in management of endovascular ischaemic stroke treatment

Application of anatomical findings of our study can prevent any advert effects during surgical procedures in the field of cerebrovascular surgery.

To the authors best knowledge, there is sparcity of previous studies that have observed the M1 segments and its early branch in south Indian population.

The study of anatomical features guide the radiologist to provide accurate angiographic results which helps neurosurgeon to plan the mode of operative procedure.

ABBREVIATIONS

cm - Centimeter No. - Number

CT - Computerised tomography

DSA - Digital subtraction angiography

EFB - Early frontal branch

ETB - Early temporal branch

ICA - Internal carotid artery

L - Left R - Right

Max - Maximum

LSA - Lenticulostriate artery

MCA - Middle cerebral artery

MRI - Magnetic Resonance Imaging

MRA - Magnetic Resonance Angiography

SD - Standard Deviation % - Percentage

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Conflicts of Interests: None

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