STUDY OF MICROSURGICAL ANATOMY OF MIDDLE CEREBRAL ARTERY IN HUMAN CADAVERIC BRAIN

THESIS

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DECLARATION

I hereby declare that this project, titled **"STUDY OF MICROSURGICAL ANATOMY OF MIDDLE CEREBRAL ARTERY IN HUMAN CADAVERIC BRAIN"** is a *bona fide* record of my original research work. It has not been submitted to any other institution for the award of any degree or diploma. Information derived from the published or unpublished work of others has been duly acknowledged in the text.

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CERTIFICATE

This is to certify that this thesis, titled **"STUDY OF MICROSURGICAL ANATOMY OF MIDDLE CEREBRAL ARTERY IN HUMAN CADAVERIC BRAIN"** is a *bona fide* work of **Dr. VISHNU GUPTA**, performed under our guidance and supervision, in the Department of Neurosurgery at All India Institute of Medical Sciences (AIIMS), Jodhpur, during the period of study for degree of **Magister Chirurgiae (MCh) Neurosurgery,** from July 2020 to June 2023.

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"From inability to let well alone;
From too much zeal for the new and contempt for what is old;
From putting knowledge before wisdom, science before art and cleverness before commonsense;
From treating patients as cases;
And from making the cure of the disease more grievous than the endurance of the same,Good Lord, deliver us".

Dr Vishnu Gupta

SYNOPSIS

***Background**:* Micro dissection of cadaver specimens is the base on which ourknowledge of the intricate anatomy of the human brain. Microsurgical Anatomy of Middle cerebral artery (MCA) is of particulate interest to neurosurgeons as it is the largest and most complex arterial system of Brain. Though various studies have been done on MCA, but no such study has been done taking into consideration large sample size of Indian population. This study will be advantageous in improving knowledge of MCA and its variations. This will prove useful for neurosurgeons in performing microsurgeries

Objective**:** Study of the microsurgical anatomy of the Middle Cerebral Artery in Human Cadaveric Brain. Comparison of the findings with the existing studies. Implication of these finding in micro-neurosurgical procedures

Materials and Methods: 16 Formalin Fixed Cadaveric brains, that had 32 vessels from its origin from Internal Cerebral Artery to M1 segment with respect to diameter, length and branching pattern were studied under high magnification (operating microscope) and the data compared with literature.

Results: Mean length of M1 was 24.1 ±11 mm with outer diameter of 3.2mm. Average number of perforators pre bifurcation was 9 and post bifurcation was 3. The pattern of branching of the main trunk was bifurcation (62.5%), trifurcation (18.75%) and others (19.75%) and among this inferior trunk dominance was seen in 70%. Average number of early cortical branch were 1 to 3 .

Conclusion**:** MCA has its variable anatomy and geographical variations . The knowledge of micro-surgical anatomy is very useful in neurosurgical procedure like MCA aneurysm surgery, STA-MCA bypass, AVM surgery and Tumour around sylvian region.

LIST OF ABBREVIATIONS

IC	Internal Carotid artery
MCA	Middle cerebral artery
ACA	Anterior Cerebral artery
OD	Outer diameter
M1	First segment of Middle Cerebral artery
M2	Second segment of Middle Cerebral artery
M3	Third segment of Middle Cerebral artery
M4	Fourth segment of Middle Cerebral artery
OFA	Orbito-Frontal artery
PTA	Posterior Temporal artery
TOA	Temporo-occiptal artery
PPA	Posterior Parietal artery
Ang.A	Angular artery
ECB	Early cortical branches
LCB	Late Cortical branches
STA	Superficial Temporal artery
PrB	Pre bifurcation
PoB	Post Bifurcation

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INTRODUCTION

Microsurgery has developed over time as a result of a better understanding of normal anatomy and the countless variations that can arise in the tiny brain regions. The foundation of our understanding of the complicated architecture of the human brain is the micro dissection of cadaver specimens. The development of micro neurosurgery and the understanding of minute perforating vessels and their patterns along the base of the brain have contributed to the long-anticipated improvements in the prognosis of patients undergoing surgery on neuro-vascular structures.

Since the Middle Cerebral Artery (MCA) is the largest and most intricate arterial system in the brain, neurosurgeons are particularly interested in its microsurgical anatomy. The Internal Carotid Artery (ICA) splits into two branches, the bigger of which is, where the MCA begins.[1, 2]

There are large number of neurovascular procedures which involves MCA and its branches. The prevalence of MCA aneurysms is approximately 14.0–43.0 % among all cerebral aneurysms. These aneurysms are usually observed to arise from the M1 bifurcation segment or the proximal M1 segment .[3, 4] In a recent epidemiological study by Duffau and Capelle,[5] insular glioma which involves MCA, accounted for up to 25% of all low grade gliomas and 10% of all high grade gliomas. Other diseases like AVM which take feeders from MCA, STA- MCA bypass which is done in Moya-Moya disease, aneurysm surgery and MCA territory stroke, also very high in number.[6] To prevent a catastrophe, the neurosurgeons must know the micro-surgical anatomy of MCA while dealing with these disease and corresponding neurosurgical procedure and also adopt the finest technique available. Also in recent era the number of neuro-endovascular procedures increases day by day. The knowledge of its course, diameter , length and branching pattern also very helpful in endovascular procedure like coiling of MCA aneurysm, Mechanical thrombectomy and embolization of MCA feeders during AVM surgery or feeders of Tumour around sylvian region.[7]

Many studies which were done previously on micro-surgical anatomy of MCA show its variable anatomy. Data available in western literature about micro-surgical anatomy of MCA shows its variable length, diameter, branching pattern, perforators origin and number and different cortical branches.[10, 11, 12, 13,] There were also variations in the anatomy of MCA in existing Indian and western literature.[14, 15] This was due to either a non-uniform classification system used for micro surgical anatomy of MCA[7] or due to geographical variations of MCA. So In our study we want to complete these shortcomings and also cover the western part of India to see any geographical variations in the anatomy of MCA.

AIMS AND OBJECTIVE

1. Study the micro-surgical anatomy of MCA and its branches.

2. Ccompares it with existing literature on micro-surgical anatomy and variations of the middle cerebral artery in the human cadaveric brain.

3. Apply its clinical significance in Neurosurgical procedures.

MICROSURGICAL ANATOMY OF THE MIDDLE CEREBRAL ARTERY [8, 9,10,11,12]

The MCA is the largest and most complex of the cerebral arteries. Some of its branches are exposed in most operations in the supratentorial area, whether the approach is to the cerebral convexity, parasagittal region, or along the cranial base. In the past, surgical interest in the MCA has been directed at avoiding damage to its branches during operations within its territory, but micro-operative techniques have now made reconstruction of and bypass to the MCA an important method of preserving and restoring blood flow to the cerebrum.

The MCA arises as the larger of the two terminal branches of the internal carotid artery. The diameter of the MCA at its origin is roughly double that of the anterior cerebral artery. Its origin is at the medial end of the sylvian fissure, lateral to the optic chiasm, inferior to the anterior perforated substance, and posterior to the division of the olfactory tract into the medial and lateral olfactory striae. From its origin, it courses laterally below the anterior perforated substance and parallel, but roughly one cm posterior, to the sphenoid ridge. As it passes below the anterior perforated substance, it gives rise to a series of perforating branches referred to as lenticulostriate arteries. It divides within the sylvian fissure and turns sharply posterosuperiorly at a curve, the genu, to reach the surface of the insula. At the periphery of the insula, the branches pass to the medial surface of the opercula of the frontal, temporal, and parietal lobes. Its branches pass around the opercula to reach the cortical surface and supply most of the lateral surface and some of the basal surface of the cerebral hemisphere.

Segments:

The MCA is divided into four segments: Ml (sphenoidal), M2 (insular), M3 (opercular), and M4 (cortical). The M1 begins at the origin of the MCA and extends laterally within the depths of the sylvian fissure. It courses laterally, roughly parallel to and approximately 1 cm posterior to the sphenoid ridge in the sphenoidal compartment of the sylvian fissure. This segment terminates at the site of a 90-degree turn, the genu, located at the junction of the sphenoidal and operculoinsular compartments of the sylvian fissure. This bifurcation occurs proximal to the genu in most hemispheres. The small cortical branches arising from the main trunk proximal to the bifurcation are referred to as early branches.

The M2 segment includes the trunks that lie on and supply the insula. This segment begins at the genu where the MCA trunks passes over the limen insulae and terminates at the circular sulcus of the insula. The greatest branching of the MCA occurs distal to the genu as these trunks cross the anterior part of the insula. The branches passing to the anterior cortical areas have a shorter path across the insula than those reaching the posterior cortical areas. The branches to the anterior frontal and anterior temporal areas cross only the anterior part of the insula, but the branches supplying the posterior cortical areas course in a nearly parallel but diverging path across the length of the insula. The frontal branches cross only the short gyri before leaving the insular surface, whereas the branches supplying the posterior parietal or angular regions pass across the short gyri, the central sulcus, and the long gyri of the insula before leaving the insular surface.

The M3 segment begins at the circular sulcus of the insula and ends at the surface of the sylvian fissure. The branches forming the M3 segment closely adhere to and course over the surface of the fronto-parietal and temporal opercula to reach the superficial part of the sylvian fissure. The branches directed to the brain above the sylvian fissure undergo two 180-degree turns. The first turn is located at the circular sulcus, where the vessels coursing upward over the insular surface turn 180 degrees and pass downward over the medial surface of the fronto-parietal operculum. The second 180-degree turn is located at the external surface of the sylvian fissure, where the branches complete their passage around the inferior margin of the fronto-parietal operculum and turn in a superior direction on the lateral surface of the frontal and parietal lobes.

The arteries supplying the cortical areas below the sylvian fissure pursue a less tortuous course. These branches, on reaching the circular sulcus, run along its inferior circumference before turning upward and laterally on the medial surface of the temporal operculum, thus producing a less acute change in course at the inferior margin of the circular sulcus. On reaching the external surface of the sylvian fissure, these branches are directed downward and backward on the surface of the temporal lobe.

The M4 is composed of the branches to the lateral convexity. They begin at the surface of the sylvian fissure and extend over the cortical surface of the cerebral hemisphere. The more anterior branches turn sharply upward or downward after leaving the sylvian fissure. The intermediate branches follow a gradual posterior incline away from the fissure, and the posterior branches pass backward in nearly the same direction as the long axis of the fissure.

Perforating Branches

The perforating branches of the MCA enter the anterior perforated substance and are called the lenticulostriate arteries. There is an average of 10 lenticulostriate arteries per hemisphere. Lenticulostriate branches arise from the prebifurcation part in every case and from the postbifurcation part in half of the hemispheres. The earlier the bifurcation, the greater the number of postbifurcation branches. The lenticulostriate arteries are divided into medial, intermediate, and lateral groups, each of which has a unique origin, composition, morphology, and characteristic distribution in the anterior perforated substance. The medial group is the least constant of the three groups and is present in only half of the hemispheres. When present, it consists of one to five branches that arise on the medial part of the M1 segment near the carotid bifurcation or an early branch, and pursue a relatively direct course to enter the anterior perforated substance just lateral to the branches from Internal Carotid Artery. The lateral and intermediate groups of lenticulostriate arteries pass through the anterior perforated substance, putamen and arch medially and posteriorly to supply almost the entire anterior-to-posterior length of the upper part of the internal capsule and the body and head of the caudate nucleus. The medial lenticulostriate arteries irrigate the area medial to and below that supplied by the lateral and intermediate lenticulostriate arteries; this area includes the lateral part of the globus pallidus, the superior part of the anterior limb of the internal capsule, and the anterosuperior part of the head of the caudate nucleus.

Cortical Distribution

The cortical territory supplied by the MCA includes the majority of the lateral surface of the hemisphere, all of the insular and opercular surfaces, the lateral part of the orbital surface of the frontal lobe, the temporal pole, and the lateral part of the inferior surface of the temporal lobe. The MCA territory does not reach the occipital or frontal poles or the upper margin of the hemisphere, but it does extend around the lower margin of the cerebral hemisphere onto the inferior surfaces of the frontal and temporal lobes. The narrow peripheral strip on the lateral surface of the cerebral hemisphere, supplied by the ACA and PCA rather than the MCA, extends along the entire length of the superior margin of the hemisphere from the frontal to the occipital pole. It is broadest in the superior frontal region and narrowest in the superior parietal area. This strip continues around the occipital pole and onto the posterior part of the lateral surface of the temporal lobe and narrows and disappears anteriorly on the temporal lobe where the branches of the MCA extend around the lower border of the hemisphere onto the inferior surface of the temporal lobe and the orbital surface of the frontal lobe.

The cortical area supplied by the MCA is divided into 12 areas

1. ***Orbitofrontal area.*** The orbital portion of the middle and inferior frontal gyri and the inferior part of the pars orbitalis.
2. ***Prefrontal area.*** The superior part of the pars orbitalis, the pars triangularis, the anterior part of the pars opercularis, and most of the middle frontal gyrus.
3. ***Precentral area.*** The posterior part of the pars opercularis and the middle frontal gyrus, and the inferior and middle portions of the precentral gyrus.

4. ***Central area.*** The superior part of the precentral gyrus and the inferior half of the postcentral gyrus.
5. ***Anterior parietal area.*** The superior part of the postcentral gyrus, and frequently, the upper part of the central sulcus, the anterior part of the inferior parietal lobule, and the anteroinferior part of the superior parietal lobule.
6. ***Posterior parietal area***. The posterior part of the superior and inferior parietal lobules, including the supramarginal gyrus.
7. ***Angular area.*** The posterior part of the superior temporal gyrus, variable portions of the supramarginal and angular gyri, and the superior parts of the lateral occipital gyri (the artery to this area is considered the terminal branch of the MCA).
8. ***Temporo-occipital area.*** The posterior half of the superior temporal gyrus, the posterior extreme of the middle and inferior temporal gyri, and the inferior parts of the lateral occipital gyri.
9. ***Posterior temporal area.*** The middle and posterior part of the superior temporal gyrus, the posterior third of the middle temporal gyrus, and the posterior extreme of the inferior temporal gyrus.
10. ***Middle temporal area***. The superior temporal gyrus near the level of the pars triangularis and pars opercularis, the middle part of the middle temporal gyrus, and the middle and posterior part of the inferior temporal gyrus.
11. ***Anterior temporal area***. The anterior part of the superior, middle, and inferior temporal gyri.
12. ***Temporopolar area.*** The anterior pole of the superior, middle, and inferior temporal gyri.

Branching Pattern

The main trunk of the MCA divides in one of three ways: bifurcation into superior and inferior trunks; trifurcation into superior, middle, and inferior trunks; or division into multiple (four or more) trunks. Most of the MCAs divide by bifurcation(80%), some by trifurcation(10%), and others by giving rise to multiple trunks. The distal division of the MCA also generally occurs in a series of bifurcations. The small arteries that arise proximal to the bifurcation or trifurcation and are distributed to the frontal or temporal pole are referred to as early branches.

The MCAs that bifurcate are divided into three groups, designated equal bifurcation, superior trunk dominant and inferior trunk dominant, based on the diameter and the size of the cortical area of supply of their superior and inferior trunks. The equal bifurcation yields two trunks with nearly equal diameters and size of cortical area. The inferior trunk supplies the temporal, temporooccipital, and angular areas, and the superior trunk supplies the frontal and parietal regions. The superior trunk usually supplies the orbitofrontal to the posterior parietal areas, and the inferior trunk usually supplies the angular to the temporopolar areas. The inferior trunk dominant type of bifurcation yields a larger inferior trunk that supplies the temporal and parietal lobes and a smaller superior trunk that supplies all or part of the frontal lobe. The maximal area perfused by the inferior trunk includes all of the territory between and including the precentral and temporopolar areas. The superior trunk dominant type of bifurcation yields a larger superior trunk that supplies the frontal and parietal regions and a smaller inferior trunk that supplies only the temporal lobe. The maximal area supplied by the dominant superior trunk includes the orbitofrontal to the temporo-occipital areas.

Stem Arteries

The stem arteries arise from the trunks and give rise to the individual cortical branches. They arise from the main trunk and the two or more trunks formed by a bifurcation, trifurcation, or division into multiple trunks. There is considerable variation in the number and size of the area supplied by the stem arteries. The most common pattern is made up of eight stem arteries per hemisphere.

The individual stem arteries give rise to one to five cortical arteries. The most common pattern is for one of the 12 cortical areas to be supplied by a stem artery supplying one or two adjacent areas. The cortical areas most commonly receiving a stem artery serving only that area are the temporo-occipital, angular, and central areas. Stem arteries supplying four or five of the cortical areas are most commonly directed to the area below the sylvian fissure.

Cortical Arteries

The cortical arteries arise from the stem arteries and supply the individual cortical areas. Generally, one, or less commonly, two cortical arteries (range, one to five) pass to each of the 12 cortical areas. The smallest cortical arteries arise at the anterior end of the sylvian fissure and the largest arteries arise at the posterior limits of the fissure. The cortical branches to the frontal, anterior temporal and anterior parietal areas are smaller than those supplying the posterior parietal, posterior temporal, temporo-occipital, and angular areas. The smallest arteries supply the orbitofrontal and temporopolar areas, and the largest ones supply the temporo-occipital and the angular areas. There is an inverse relationship between the size and number of arteries supplying a cortical area. The temporo-occipital area has the smallest number of arteries, but they are the largest in size, and the prefrontal area has the largest number of arteries, but they are smaller. The temporopolar, temporo-occipital, angular, and anterior, middle, and posterior temporal arteries usually arise from the inferior trunk; the orbitofrontal, prefrontal, precentral, and central arteries usually arise from the superior trunk. The anterior and posterior parietal arteries have an origin evenly divided between the two trunks and usually arise from the dominant trunk.

Early Branches

The cortical arteries arising from the main trunk proximal to the bifurcation or trifurcation are called early branches. The early branches are distributed to the frontal or temporal lobes. Nearly half of MCA send early branches to the temporal lobe, but less than 10% give early branches to the frontal lobe. The temporal branches usually supply the temporopolar and anterior temporal areas. The frontal branches terminate in the orbitofrontal and prefrontal areas. A few MCAs will give rise to early branches to both the frontal and temporal areas.

Anomalies

Anomalies of the MCA, consisting of either a duplicate or an accessory MCA, are infrequent and occur less often than anomalies of the other intracranial arteries. A duplicated MCA is a second artery that arises from the internal carotid artery and an accessory MCA is one that arises from the anterior cerebral artery. Both the duplicate and accessory MCA send branches to the cortical areas usually supplied by the MCA. The accessory MCA usually arise from ACA, IC, AchA or PcomA. The accessory MCA arising from ACA is differentiated from a recurrent artery of Heubner by the fact that the recurrent artery, although arising from the same part of the anterior cerebral artery as an accessory MCA, enters the anterior perforated substance, but the accessory MCA, although sending branches to the anterior perforated substance, also courses lateral to this area and sends branches to cortical areas normally supplied by the MCA.

EMBRYOLOGY OF MCA[16]

Padget's detailed description of the development of cranial arteries, published in 1948, provides useful information about the embryology of MCA. When the embryo is 28–30 days old (crown-rump length 4–5 mm), internal carotid artery (ICA) divides into a cranial and a caudal branch (Fig. 1A). The ACA is a continuation of the cranial branch, and MCA is one of its collaterals. The caudal branch later develops into a posterior communicating artery. When the embryo is 31–33 days old (7–12 mm), the primary cranial branch of ICA gives rise to several branches. The largest of these is the primitive anterior choroidal artery (Fig. 1B). At 34–36 days of the embryonal stage (12–14 mm), the anterior choroidal artery becomes quite prominent. Just distal to the anterior choroidal artery, multiple plexiform arterial twigs appear, which later develop into lateral striate arteries and the trunk of MCA by fusion and regression (Fig. 1C). The terminal end of the cranial division of the carotid constitutes the primitive olfactory artery (POA). It has two branches, a primary branch to the nasal fossa, and a secondary branch passing more medially to the emerging olfactory nerve root. The latter is the medial olfactory artery, which joins with the artery from the contralateral side, in the mid-line region of the future anterior communicating artery. By 39–41 days of the embryo (16–18 mm), the MCA becomes a prominent stem, with with plexiform arteries, which enter the lateral part of anterior perforated substance, for supply to the striatum. At 43–45 days of the embryo (20–24 mm), the POA dwindles. On the other hand, larger derivatives of the POA extend laterally, to enter the mesial part of the anterior substance, for supplying the basal ganglia (Fig. 1D). They are the recurrent artery of Heubner (RAH) and medial striate arteries, which may have potential anastomosis with lateral striate groups (Fig. 1E). Finally, at 40 mm stage of the embryo, the MCA attains approximate adult configuration (Fig. 1F).

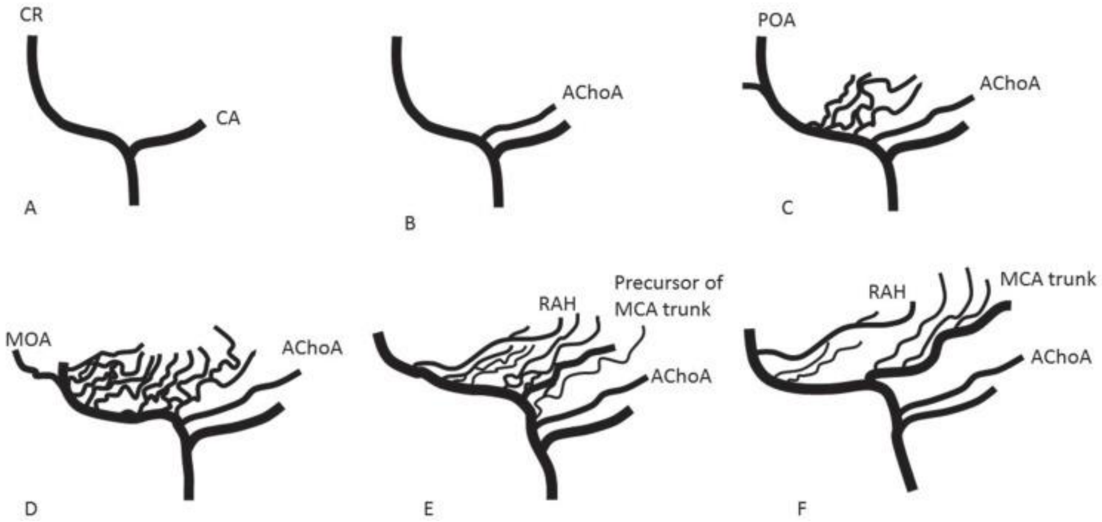


Figure 1: Schematic representation of the formation of internal cerebral artery (ICA), anterior cerebral artery (ACA), and middle cerebral artery (MCA). A. ICA divides into a cranial branch (CR) and a caudal branch (CA). B. Anterior choroidal artery (AChoA) arises from the CR. C. Multiple plexiform arterial twigs appear just distal to the ACoA. The terminal end of CR constitutes the primitive olfactory artery (POA). D. The POA dwindles. Medial olfactory artery (MOA), which will constitute the ACA, branches out from the POA. E. Multiple plexiform arterial twigs evolve into recurrent artery of Heubner (RAH), medial and lateral striate arteries, and a single MCA trunk. F. Adult configuration of cerebral arteries of anterior circulation. (Printed from "Padget DH. The development of the cranial arteries in the human embryo")

REVIEW OF LITERATURE

The advent of microsurgical techniques in cerebrovascular surgery has interested many like, *Chater et al* (1976), *Grand et al* (1980)[10], *Gibo et al* (1981)[11], *Umnasky et al* (1984)[12], to do research on micro surgical anatomy of cerebral vasculature.

Yasargil M.G. (1984)[13] states that in 70% of cases MCA was larger than ACA. The infromedial perforators of M1 segment of MCA ranged from 2-15 in number. Yasargil has demonstrated fenestrated M1 segment as a rare anomaly encountered.

Gibo et al (1981)[10] states that in bifurcating MCA 28% had superior trunk dominance, 32% had inferior trunk dominance, 18% had equal division.

A.L. Rhoton (1984)[14]1 has stated that the MCA outer diameter to be 3.5mm on average. There are 4-6 early branches per hemisphere, the size of each vessel varied depending on the cortical area supplied. The anteroinferior part of the limiting sulcus is devoid of large perforating vessels and it is the safe area to make insular cortical incision. *A.L. Rhoton* has stated that the number of inferiomedial perforators varies from 1-21 in numbers per hemisphere.

Umnasky et al[12] states that M1 length was 15.7mm on an average. Of all the perforators of MCA 79% were from M1, 15.3% was from secondary trunks and 5.7% was from early temporal and frontal branches.

SB Pai et al[15] states The outer diameter of the MCA main trunk ranges from 2.5 to 4 mm with a mean of 3.35 mm. The superolateral branches consisted of polar temporal artery and anterior temporal artery that had a common origin and sometimes the uncal artery or the accessory uncal artery. Perforators or lenticulostriate arteries were seen in the inferiomedial surface all along the length of M1. Eight bifurcations and two trifurcations were noted.

R Sriniwasa et al[19] showed that The main trunk of MCA was 16±3 mm long with no significant differences between both sides. Its outer diameter was 3±0.1 mm. Among the early branches 58% were destined to the temporal lobe. Distance between the origins of the early branch from MCA origin was 4±2mm on the right side and 4.5±2.5 mm on the left side. The most consistent perforating branch group was the intermediate group. The pattern of branching of the main trunk was bifurcation (73%), single trunk (10%) and trifurcation (10%). Within the bifurcation group, inferior trunk dominance was seen in 50%. Amongst the cortical branches diameter of the angular artery was largest and the temporo-polar was smallest. No significant difference in the data as compared to literature.

Hema.N et al[22] states that 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 LSA was 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).

R. Jayekumar et al[23] states that 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%.

K. Cilliers et al[24] studied 40 MCA vessel and observed that that Most commonly duplicated was the anterior parietal artery in 30.0%, and most commonly absent was the common temporal artery in 65.0%. . Criteria were described for the bifurcation subtypes and medial bifurcation (50.0%) was most commonly observed. No anomalies were observed

MATERIAL & METHODS

Sixteen formalin fixed adult cadavers with 32 MCA vessels were examined in the Anatomy dissection hall of the All India Institute of medical science, Jodhpur between January 2021 to December 2022.

Entire dissection was carried out under operating microscope with 20 x zoom (Gem 04, Gem optical Ambala, Haryana, India).

Digital Vernier caliper (YURI-04, Yuri, China) with accuracy of 0.1mm used for Measurements. Other instruments electric cutter, toothed forceps, needle, syringe, cotton, scissors, 11 no. blade knife, curved and straight artery forceps were used.

Apple Ipad air 3 (Apple, California, United states of America) was used for taking high definition photographs.

Procedure

After retrieval of brain from skull vault, the dura was opened from the frontal base in a transverse direction, and after cutting the falx, the frontal lobes 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 tentorial hiatus, the brain stem along with the basilar artery was cut, and entire cerebral hemispheres delivered, after dividing the posterior attachment of falx. Further dissections were carried out using microscope with 20 X 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 was traced, and then the course and branching of MCA was traced.The M1 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 patterns of MCA into different trunks were noted. The distributions of the early cortical branches were noted. The entire architecture of MCA and its branches were photographed.

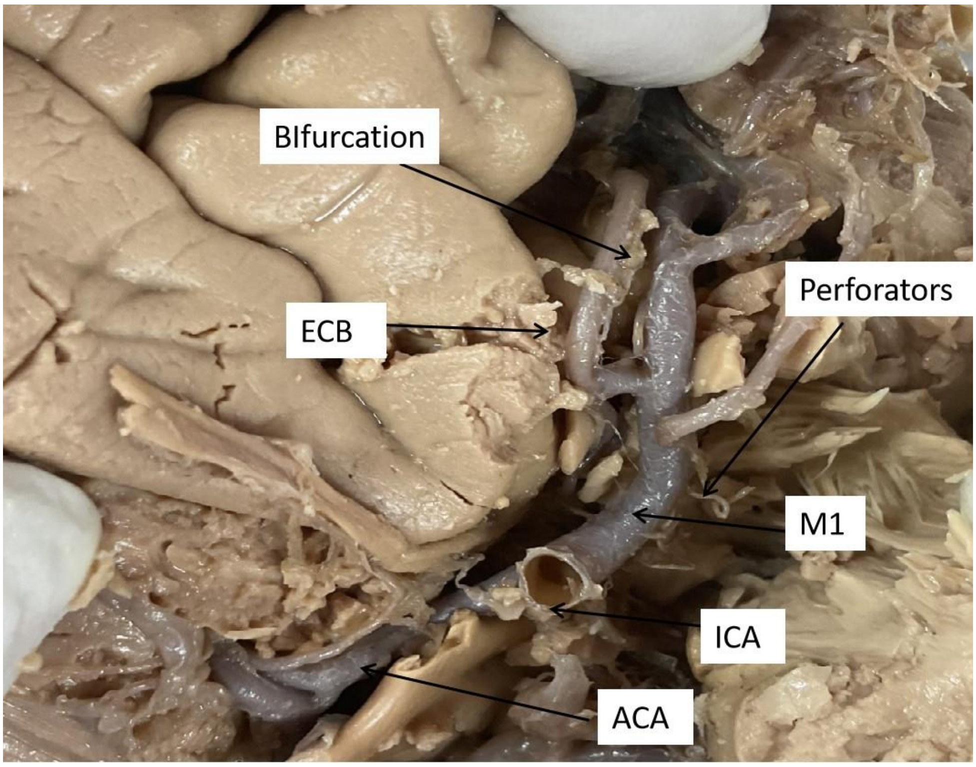
OBSERVATIONS

The following observations and measurements made.

1. Middle Cerebral Artery outer diameter (just distal to division)
2. Length of M1 segment of Middle Cerebral Artery Length
3. Internal Cerebral artery outer diameter (Just proximal to ICA division)
4. Early Branches (Cortical vessels arising from M1)
5. Accessory MCA (May be from ACA, ICA, Anterior choroidal artery)
6. Perforators
    1. M1 Perforators
        a. Proximal
        b. Distal
7. Division of Middle cerebral artery.
    a) Bifurcation
    b) Trifurcation
    c) Multiple Branches
8. Dominance of the trunk.
9. Origin of each cortical vessel from the trunk.
10. Smallest and largest cortical vessel.

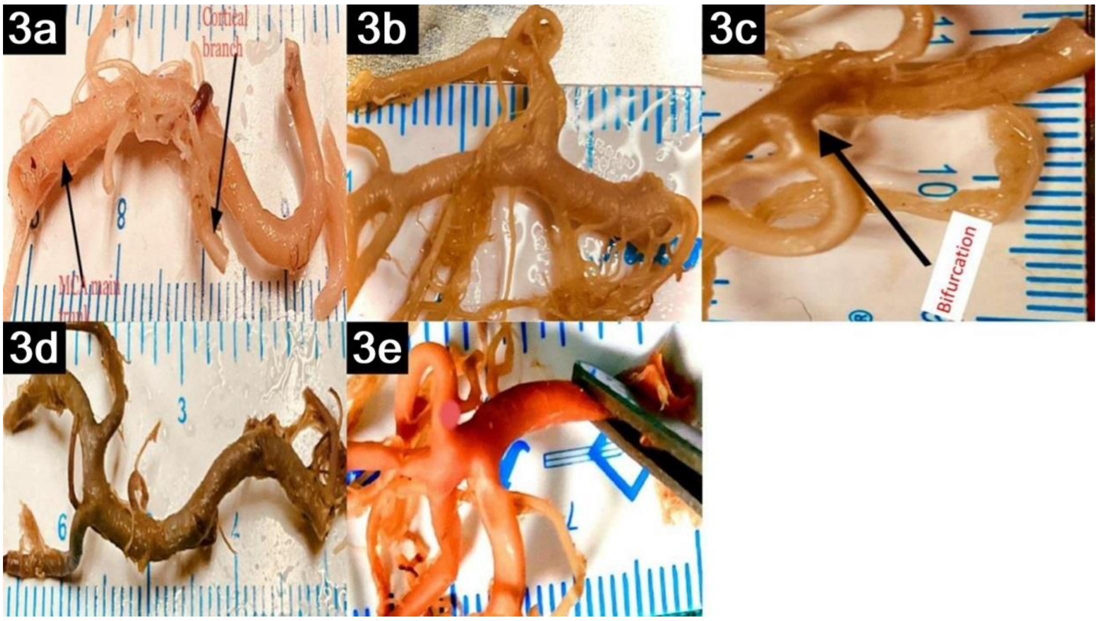
RESULTS AND ANALYSIS

The origin, course, morphometric and branching pattern of MCA was studied (figure 2). A total of 32 formalin fixed cerebral hemisphere were examined. The average outer diameter (OD) of ICA was 3.6 mm ranges from 2.5 mm to 5.4 mm. Than ICA further divides into MCA and Anterior Cerebral Artery (ACA). There was no accessory and additional MCA were noted. The average outer OD of MCA was 3.2 mm ranges from 2.3 mm to 4.8 mm. The average length of M1 segment from origin to genu was 24.1 mm, shortest being 11 mm while 34 mm was longest found.



Figures 2: Normal anatomy of MCA (MCA- Middle cerebral artery, ACA-Anterior Cerebral artery, ICA- Internal Cerebral artery, ECB- early cortical branches)

Main trunk of MCA was further divided into multiple branches or runs as a single trunk (figure 3). Sixty two and half percent MCA had bifurcation, 18.75 % had trifurcation, 12.5 % had tetrafurcation and in 6.25% of specimens MCA runs as a single trunk. Pseudo trifurcation[7] was also noted on 3 samples, which was included in bifurcation group. Fifty five % of MCA had inferior dominance, 34.37 % had superior dominance while in 15.6 % of sample there was no dominance seen.



1) **Figure 3**: Various branching pattern of MCA

(2a) Single stem (2b) Bifurcation (2c) Pseudobifurcation (2d) Trifurcation

(2e) Tetreafurcation

The whole length of M1 segment of MCA had numerous perforators before bifurcation and after bifurcation named as pre bifurcation and post bifurcation group (figure 4). In this study we found average 9 perforators before bifurcation with minimum of 3 in one specimen while maximum 15 in one specimen. The numbers of perforators arise after post-bifurcation were less in number with average of 3, ranges from 1 to 7. Pre-bifurcation group of perforators further subdivided into three subgroup: Inferiomedial group, intermittent group and inferolateral group (figure 5). The inferiolateral sub group was more consistent found in 26 specimens, The Inferiomedial subgroup was found in 23 specimen and Intermittent group was found only in 19 specimen.

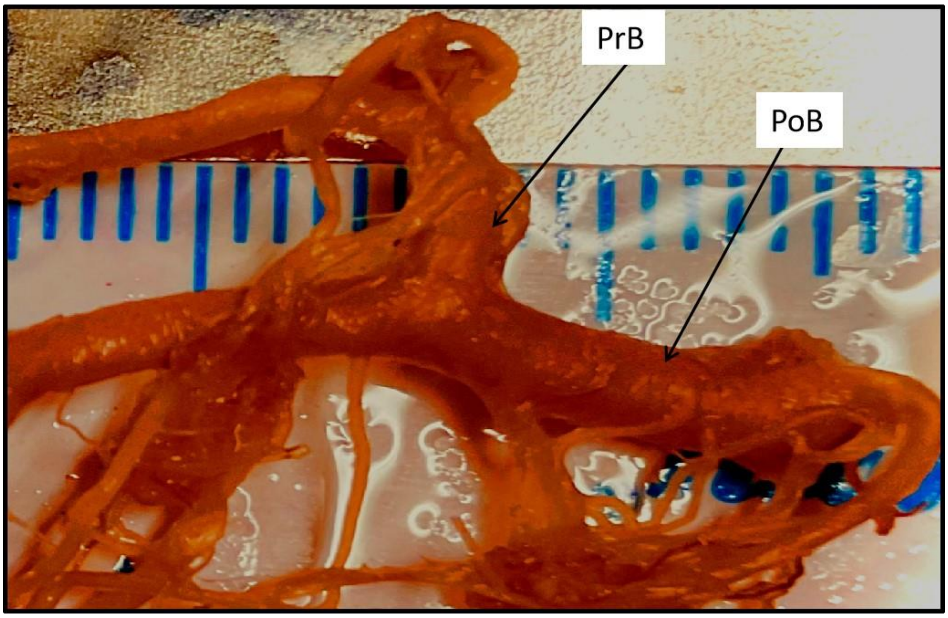


Figure 4: Perforators arise from M1 trunk of MCA (PrB- pre-bifurcation, PoB- post bifurcation)

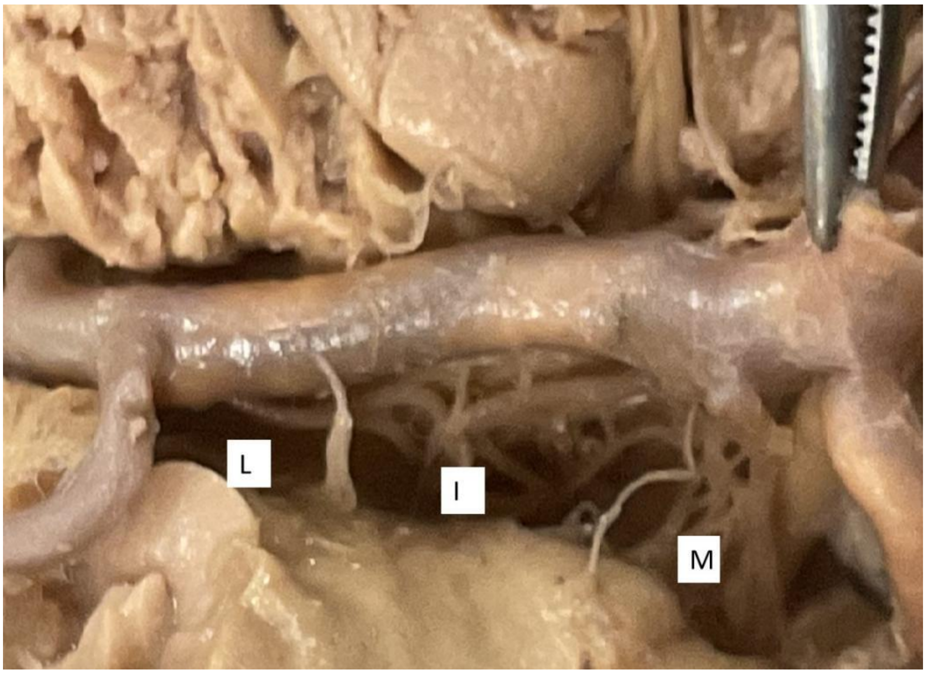


Figure 5: Perforators arise before pre bifurcation of M1 segment (M-medial group, I-intermittent group, L-lateral group)

There is substantial deviation in the size; number and origin of the MCA cortical branches.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 in our study. In this study we found 50% had 1 early branch, 30.25 % had 2 early branches and 19.75% had 3 early branches. (Figures 6 and 7)

The temporopolar artery was the smallest and shortest artery and the posterior parietal artery was the largest and longest cortical branch. Most commonly absent was the common temporal artery in 56.25%. The inferior trunk usually gave rise to the temporal arteries and the superior trunk typically gave rise to the Orbito-frontaL artery and posterior frontal artery, precentral and central arteries. The angular artery and parietal arteries originated from either the superior or the inferior trunk. The temporopolar artery (53.12%) and the prefrontal artery (28.12%) typically originated as early branches.

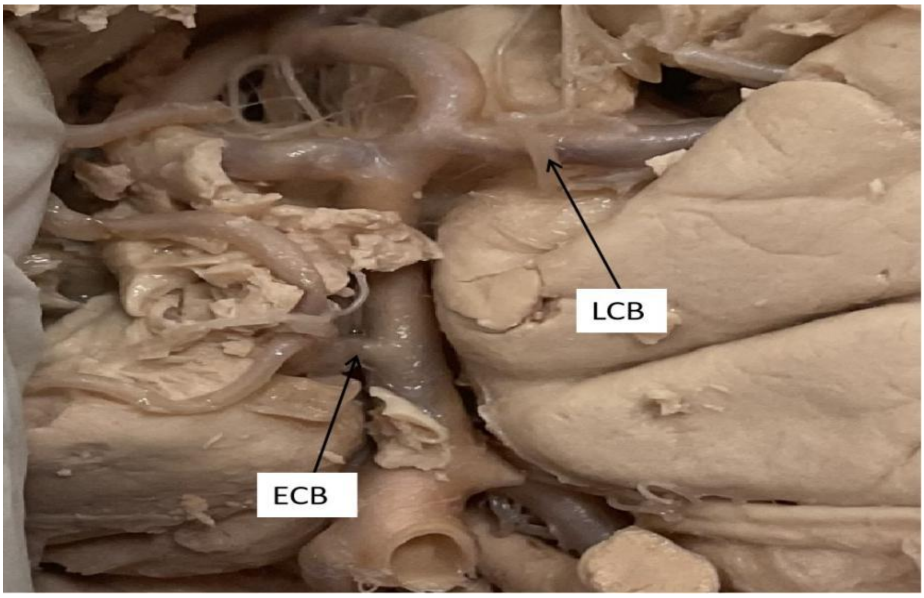


Figure 6: early cortical branches arises from pre-bifurcation of MCA (ECB- Early cortical branches, LCB-Late cortical branches)

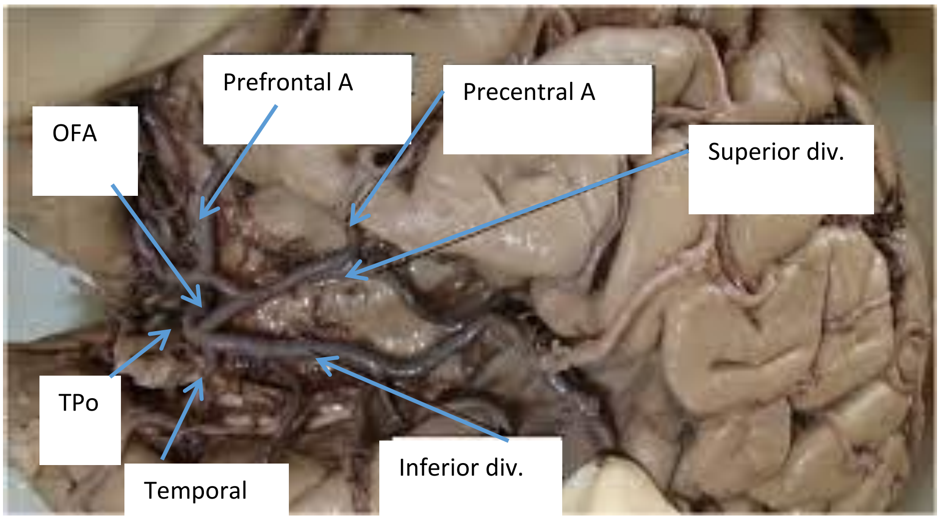


Figure 7- Various cortical branches from MCA and its trunks

COMPARISON OF DATA

The present study on the micro surgical anatomy of middle cerebral artery in our population had some significant difference when compared with similar studies in literature done on western population and other regions of Indian population.

1) MCA Outer Diameter :

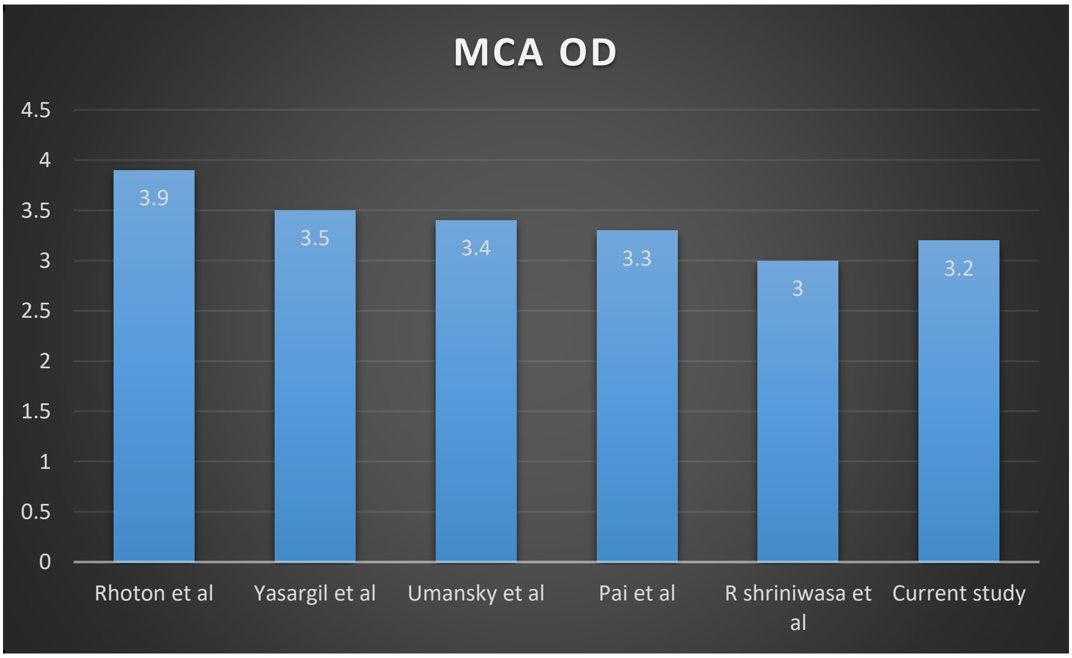


Figure 8: MCA OD in Various studies

The outer diameter of MCA was comparable to other western and Indian studies. There was no such difference in the outer diameter of MCA. Maximum in *Rhoton et al*[9] and minimum in *R Shriniwasa et al*.[19] In Current study it was 3.2 mm.

2) Length of M1 segment of MCA

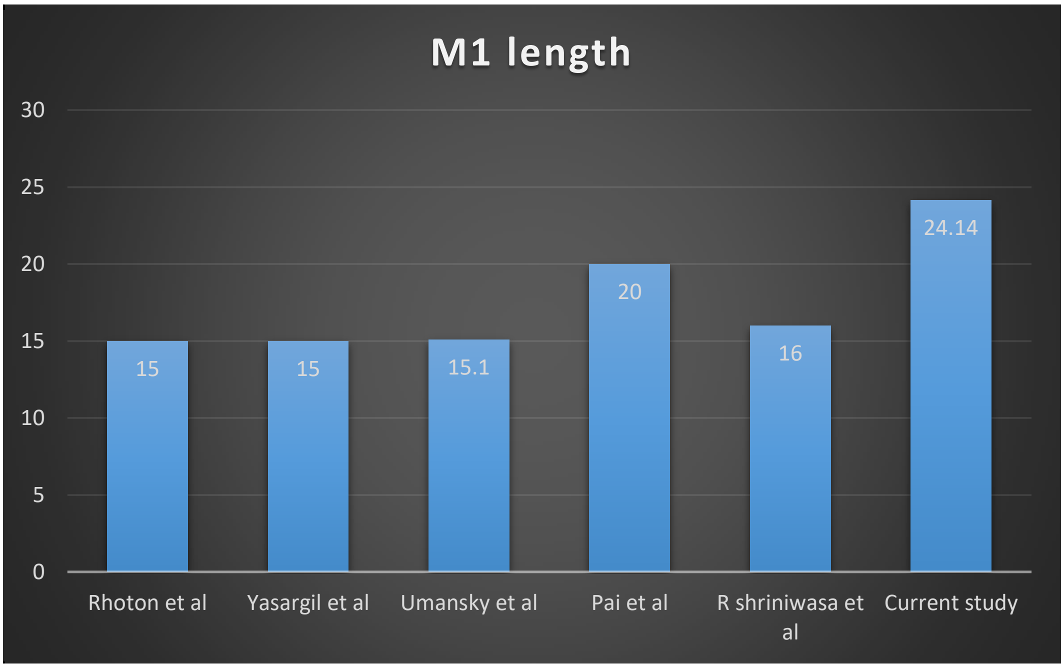


Figure 9: Length of M1 segment in various studies

There is difference in the length of M1 in Indian and western studies. The Length of M1 is slightly shorter in western literature when compared to Indian literature except study by R. *Shriniwasa et al*, [19] in which he found shorter length of M1. In current study the length of M1 is slightly higher in comparison to other study.

3) Branching pattern of MCA-

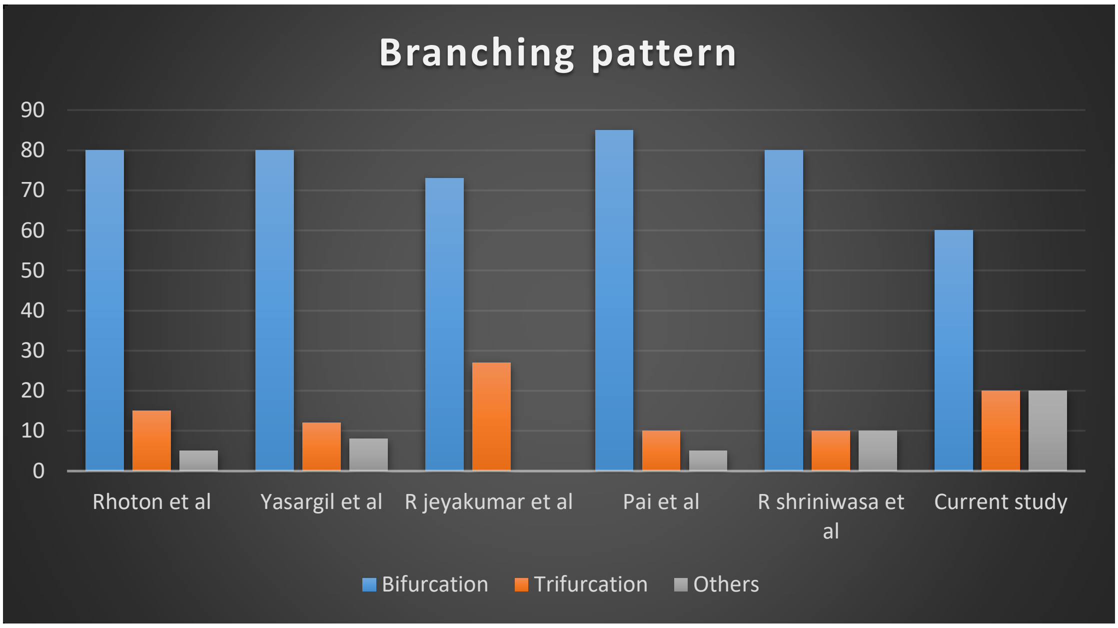


Figure 10: Branching pattern of MCA in Different studies

Branching pattern of MCA into various trunks was different from other studies. In this study we found less bifurcation compared to other western and Indian studies. MCA divides into more than 3 trunks or single MCA trunk was found in 18.75% of specimen.

4) Dominance of Trunk

Table 1: Dominance of trunk in various studies

S.No	Study	Year	Dominance
1	*Rhoton et al*	1979	Inferior
2	*Yasargil et al*	1977	Inferior
3	*Umansky et al*	1983	equal
4	*Pai et al*	2005	Inferior
5	*R shriniwasa et al*	2021	inferior
6	Current study	2022	Inferior

Most of the studies showed inferior trunk dominance similar to our studies. Only study by *Umansky et al*[12] showed that there was equal dominance of both trunk.

5) Perforators of MCA

Table 2: Numbers of perforators and their distribution along MCA in various studies

Study	Perforators
Jain et al[20]	Proximal half 54 %, distal half 26%, PoB-20%
Grand et al	Proximal half 14 %, distal half 39%, PoB-47%
Umansky et al	79% PrB and 21% PoB
Ture et al[21]	78% PrB, 4% PoB and 18% from Cortical branches
SB Pai et al	Mostly PrB , all 3 group (M, I, L) were equal
Current study	Average- 12 (9 PrB and 3 PoB), all 3 group (M, I, L) were equal

(MCA- Middle Cerebral Artery, PrB- Pre-bifurcation, PoB-Post-bifurcation,

M-Medial group, I-Intermittent group, L-lateral group)

The average number of perforators and their origin were different in different studies. In our study Average no perforators were 12 from M1 segment, nine were pre bifurcation and 3 post bifurcation with nearly equally distribution in medial, intermittent and lateral group.

6) Cortical branches from MCA

Table 3: Early cortical branches in different studies with smallest and largest cortical artery

S.No	Study name	Year	ECB to frontal /temporal	Largest cortical branch	Shortest cortical branch
1	*Gibo et al*	1981	44 %	Ang. A TOA	
2	*F. Umansky et al*	1984	Avg. 2	Ang. A	TPA
3.	*Rhoton et al*	1979	Avg. 1	Ang. A	OFA
4	*R shriniwasa et al*	2021	Avg 2	TO A Ang. A	OFA
5	*R.Jayekumaret al* [23]	2018	33.3 - 1 44.6- 2 20 %- 3	TO A Ang. A	
6	*Tanriover et al* [25]	2003	32 %	PPA	
7	Current study	2022	50%- 1 30.25 %-2 19.75 %- 2	PPA	TPA

(ECB- Early cortical branches, Ang.A- Angular artery, TOA- Temporo- Occiptal artery, OFA- Orbito- Frontal artery,TPO- temporo-Parietal artery, PPA- Posterior Parietal artery).

Most of the studies had early branches with average no 1 or 2. Different studies had different shortest and different largest artery. In our study PPA was largest while TPA was smallest artery.

DISCUSSION

Since the development of micro neurosurgical techniques in cerebrovascular surgery, several researchers have become interested in the micro-surgical anatomy of the MCA. The most significant studies were those by Grand (1980)10, Gibo et al. (1981),11 Umansky et al. (1984)[12], and Yasargil.[13]

Numerous cadaveric intravascular injection techniques have been investigated using different fixation techniques. Umansky et al.[12] listed the numerous injection techniques in their review article. Galen (c. 130 to 200 A.D.) was able to investigate the location of the vessels in the brain by inflating them with air, but the greatest advancement in the rapid development of injection techniques for anatomical research came with de Graaf's invention of the injection syringe in 1668.[17]

By the 18th century's close, capillary network visualization was accomplished using gelatin and wax and varnish media for big channel injections.. The use of this injection technique in the unfixed brain and the aid of the operating microscope allowed us to obtain good dissection, precise measurements, and excellent visualization of the course and relationship of the vessels. Despite the great interest in visualizing the cerebral vessels by means of intravascular injections, descriptions of the brain vasculature before the 19th century were purely morphological. In 1874,28,29 Duret ~2 injected human brains with gelatin colored with carmine and described the cortical and central branches of the MCA.30 In 1907, Beevor[28] outlined the vascular territory of the MCA by injecting the three cerebral arteries with gelatin and different soluble coloring agents. In 1927, Foix and Levy published a paper in which they described the anatomical basis of the clinical syndromes resulting from occlusion of the cortical branches of the MCA. Surgical interest in the anatomy of the artery developed when neurosurgical techniques advanced, and cerebral angiography was introduced by *Moniz*.[31] The intra-arterial injection's addition of red pigment makes it simple to distinguish between arachnoid strands and extremely small branches. However, in our study, adequate lighting, magnification (5-20x), and mesial dissection were employed to address the aforementioned shortcoming.

The morphometric measurements including MCA length, MCA outer diameter and ICA OD are compared to other western and Indian studies (Figure 8, 9). We found the length of M1 segment (24.2 mm) was slightly higher than other studies. The MCA OD and ICA OD was similar to other studies this is may be due to geographical variation or difference in the nomenclature used in previous studies. The current existing nomenclature of the MCA is controversial. There is often discrepancy in the literature in microsurgical anatomy of the MCA (Table 4). The OD MCA (3.2mm) was comparable to other studies (Figure 8).

Table 4: Definition Of M1, M2 segment used in different studies

S.No	**Study**	**M1 Segment definition**	**M2 segment definition**
1.	Fisher,[32] 1938	The horizontal initial segment of the artery from the carotid internus to the 90° angle/kneeof the anterior cerebri media	Insular segment that ascends towards the back and with 2–3 main branches that tightly rest on the brains' insular region;

			on the lateral view, it runs in the arterial axis (Moinz) of the brain, and in the anterior view it ascends almost vertically
2.	Gibo,[11] 1981	Begins at the origin of the MCA and extends laterally within the depths of the Sylvian fissure; the segment terminates at the site of 90° turn, at the genu, located at the junction of the sphenoidal and operculoinsular compartment of the Sylvian fissure; the M1 segment is further divided into pre-bifurcation (main trunk extending from the origin to the bifurcation) and post-bifurcation (runs parallel, diverging only minimal till it reaches genu)	Begins at the genu of the MCA where the trunks pass over the limen insulae, terminating at the circular sulcus of the insula
3.	Umansky,[12] 1984	"Main trunk" of the MCA as a portion of the artery situated between its origin at the ICA bifurcation and its division what is called "main division"	The arteries resulting from the main division are referred to as "secondary trunks" that are named "superior," "middle," or "inferior" based on the

			way in which the main trunk of the MCA is divided
4.	Türe,[21] 2000	Extends from the ICA bifurcation to the main MCA bifurcation, which is located adjacent to the limen insulae	Extends from the main bifurcation to the peri-insular sulci
5	Rhoton,[9] 2002	Begins at the origin of the MCA and extends laterally within the depths of the Sylvian fissure; it courses laterally, roughly parallel and approximately 1 cm posterior to the sphenoid ridge in the sphenoidal compartment of the Sylvian fissure; the M1 is further subdivided into “pre-bifurcation” and “post-bifurcation”; the pre-bifurcation is composed of a single trunk extending from the origin to the bifurcation, and post-bifurcation trunks off the M1 segment, runs in parallel course diverging only minimally before reaching the genu	Includes the trunk that lies on and supports the insula; the segment begins at the genu where the MCA trunks pass over the limen insulae and terminates at the circular sulcus of the insula

Branching pattern of MCA was also variable in different studies. Most common sub type seen was bifurcation followed by trifurcation than other types .Eleven different branching types can be distinguished from the literature and these include bifurcation subtypes (medial bifurcation, lateral bifurcation, medial pseudobifurcation, and lateral pseudobifurcation), trifurcation subtypes (true trifurcation, pseudotrifurcation, proximal trifurcation, and distal trifurcation), monofurcation, tetrafurcation, and pseudotetrafurcation (figure 11) (given by k ciilers et al)[24]

But most of the study includes only bifurcation, trifurcation, tertafurcation and monofurcation. There were no clear criteria for branching pattern used in these studies. We found only 60% had bifurcation while most of other studies observed bifurcation pattern in 80 % or above. The other branching pattern like trifurcation, tetreafurcation or single stem which was observed in 37.5% specimens in this study were less seen in others studies. This may be due to either different nomenclature used in different studies or geographical variation of MCA.

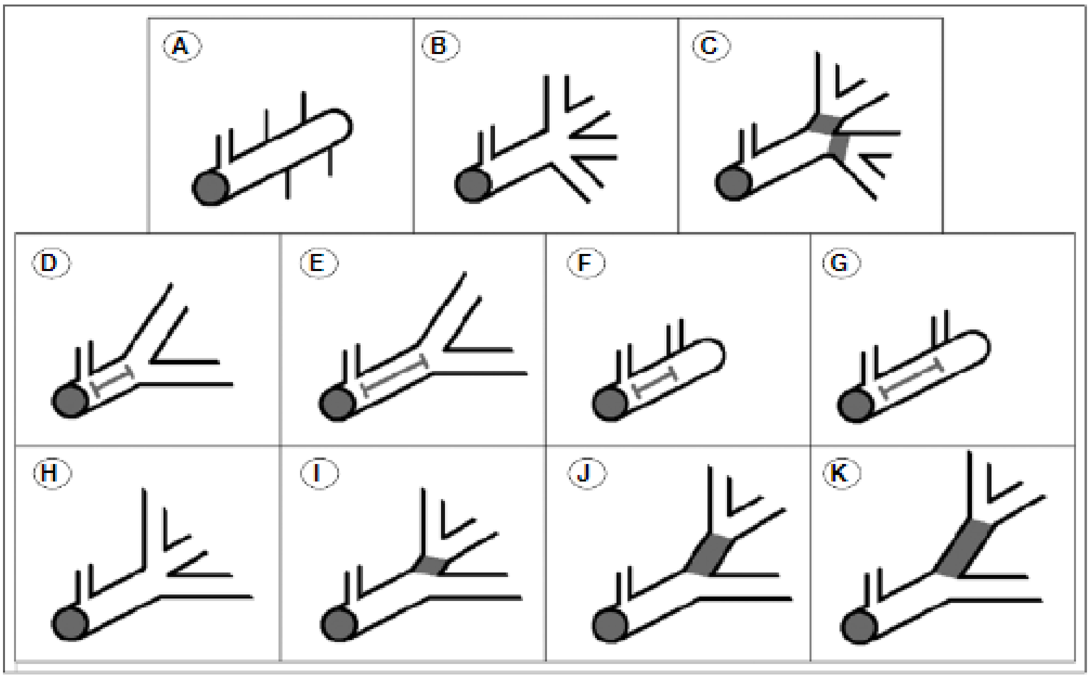


Figure 11: The 11 different branching patterns of the middle cerebral artery. A) monofurcation; B) tetrafurcation; C) pseudotetrafurcation; D) medial bifurcation; E) lateral bifurcation; F) medial pseudobifurcation; G) lateral pseudobifurcation; H) true trifurcation; I) pseudotrifurcation; J) proximal trifurcation; and K) distal trifurcation (printed from *k ciilers et al* 2003) [24]

The Inferior trunk was dominant in our study which was similar to many studies (table 1). So inferior trunk supplied a maximum area of brain and if it occluded than it causes more neurological deficit.

Perforators arise from whole segment of M1 both from pre and post bifurcation segment. There were many studies observed the number of perforators and their origin (table 2) with slight differences. We found that the more number of perforators arise in pre bifurcation group from inferior surface of M1. Lateral subgroup was more consistent followed by medial than intermittent group. These finding are similar to most of the previous studies. They also found that perforators mostly arise from pre-bifurcation part of M1 segment. Post bifurcation part of MCA had less number of perforatrs.But in study by Grand et al,[5] he found that perforators mostly arises from post bifurcation part.

Early cortical branches which were 1 to 3 in our study are comparable to other studies. Early cortical branches were mostly OFA and TPA in our studies, and supplied mostly the Frontal and Temporal region of brain these early cortical branches can be confused for main bifurcation of MCA during surgery. So it is crucial to differentiate them from main trunk. These cortical branches supplies to a specific area of brain and should be preserved during surgery in around MCA to avoid post-operative neurological deficit. Also they have also significance in MCA stroke which (embolic type) which involves MCA bifurcation area. Normally area supplied by these early cortical branches is spared.

Clinical significance:

1. MCA aneurysm surgery:

Aneurysms in the MCA are fairly common. 14.1% of MCA aneurysms in the ***ISTAT*** [3] trial were found to be close to, distant from, or adjacent to a bifurcation. In another aneurysm study, ***ATENA***, [33] MCA aneurysm prevalence was 29.5%. The prevalence of MCA aneurysms, according to various studies, ranges from 15 to 40%.[34, 35] Therefore, understanding the anatomy of microsurgery is essential. The length of the MCA segment and its multiple branching patterns are related to the development of aneurysms. During aneurysm surgery temporary clipping of the MCA during MCA bifurcation aneurysm surgery cannot be considered absolutely safe, as perforators in the segment distal to the clip would be devoid of blood supply. Temporary clipping if found to be essential should not be applied just before bifurcation. The M1 segment should be traced proximally to apply temporary clip. Irrespective of the adequate length of MCA it is not freely mobile, and mobility is being restricted by the perforators.Furthermore MCA exposure should not be done in its inferior surface as it can cause damage to the perforators. Most of MCA aneurysm located at the bifurcation of MCA so the knowledge of early cortical branches very crucial during aneurysm clipping. While dissecting the sylvian fissure from medial to lateral side, Neurosurgeon can be confused by these early branches for bifurcation and can cause blunders. So neurosurgeons should be aware to these branches mostly supplying the Frontal and Temporal region. The knowledge of these early branches also helpful in endovascular procedure while negotiating the catheter.

2. STA- MCA Bypass:

The superficial temporal artery-middle cerebral artery (STA-MCA) bypass was introduced by professor *Yasargil* in the late 60s.[18] since then this technique has been widely used in neurosurgery. Considered as the basic bypass to perform a low-flow revascularization in neurosurgery, this technique provides a blood flow augmentation to the anterior circulation of the brain from the external carotid artery. It was modified and developed during these last decades depending on the case and the indication.[36, 37]

Cerebrovascular disease brought on by atherosclerosis is the most frequent cause of hemodynamic stroke. The ICA or MCA is blocked in cerebrovascular steno-occlusive disease. The annual risk of stroke on the same side is 5.9%, and the chance of another stroke after carotid artery obstruction is 7%. Here, shunting an athero-occlusive stenosis even when there is ischemic but salvageable tissue or preventing stroke are the primary objectives of STA-MCA bypass. A large stroke on CT or magnetic resonance imaging (MRI) contraindicates bypass surgery because the brain tissue is not salvageable, and the blood flow augmentation may precipitate a hemorrhagic conversion. Even this indication remains controversial, the Saint Louis carotid stenosis study and the Japanese extracranial-intracranial bypass trial study showed better outcome for patients with stroke who underwent bypass surgery.[38] the results of medically-treated patients are poor, STA-MCA bypass may provide better outcome. A CBF and brain metabolism study is essential in preoperative study for the success of this procedure. It allows a better selection for patients who present mismatches between blood supply and brain metabolism which increases the benefit of revascularization.

Moyamoya disease is another indication for STA-MCA bypass. Takeuchi and Shimizu were the first to describe this cerebrovascular condition, which is characterized by a gradual blockage of arteries surrounding the carotid artery. As a result of this obstruction, thin collateral vessels will form, appearing as a "puff of smoke" on an angiogram. Patients with moyamoya disease symptoms should consider surgery. The aim of moyamoya disease treatment is to increase cerebral blood flow. Although encephaloduroarteriosynangiosis (EDAS) can be employed as an indirect technique, the best revascularization strategy is still debatable. STA-MCA bypass allows for direct revascularization.[39,40] Bypass surgery is also used in the management of complex aneurysms.Anastomosis is considered when a sacrifice of parent vessel or one of its major branches is necessary. Even for complex ICA aneurysms, a high-flow bypass is sometimes recommended, STA-MCA bypass can be used in complex MCA aneurysms as a rescue bypass to provide a flow replacement before exclusion of the parent vessel.[41]

Flow replacement may also be considered in skull base lesions involving vessels. Moreover, this indication remains controversial, in skull base cases, usually in almost cases there is a plan allowing peeling of the tumor from adjacent vessels. If the tumor is adherent to the vessel, it can be left to be managed conservatively and followed up by MRI or treated with radiosurgery.[41]

Finally, STA-MCA bypass is also indicated in the incidental injury of MCA during aneurysm surgery or tumor removal when a direct repair of the vessel is not possible.

The knowledge of these cortical branches is essential to do STA-MCA bypass. As previous literature suggest the diameter should be more than 3 mm for STA-MCA by-pass so Temporal artery and Temporo-occipital artery was preferred which was also found had good diameter in our study. In recent literatures this concept was abandoned. In recent literature the diameter should be at least 1 mm for a successful revascularization. Also the mobilization of MCA should be minimal to avoid injury to perforators. Also to reduce tension in STA- MCA anastomosis the length of STA and MCA branch should be adequate.

3. **Artrio-Venous Malformation:**[42,43]

Each cerebral arteriovenous malformation (AVM) represents an abnormal vascular network (the nidus) of dilated and tortuous arteries and veins without a capillary bed among them or with some microvasculature in its nidus.The AVMs receive one or more feeding arteries, and contain the intranidal network, as well as one or several draining veins. the anatomic knowledge of the feeders is clinically very important for several reasons. Firstly, the involvement of certain feeders and location of their AVMs can usually explain neurologic signs and symptoms in patients. Secondly, feeders are used during the endovascular interventional radiologic procedure. Thirdly, some feeders are the site of neurosurgical intervention. Finally, they can be the site of arterial aneurysms. A study by B. Milatović, et al the feeders most often originated from the middle cerebral artery (MCA; (23.38%). either endovascular embolization of these feeders or surgical excision of AVM is mainstay of treatment. so the idea of MCA branching pattern, origin of perforators and and its cortical branches anatomy is compulsory.

4. Ischemic Stroke:[7]

MCA and its branches are most frequently affected by ischemic strokes. The clinical outcome depends on where the occlusion is because the MCA distribution is where ischemic strokes most frequently occur. The region at risk is greater the closer the obstruction is to the site since it is thought that emboli lodge at branching points. A less severe vascular area injury should result from MCA occlusions distal to the bifurcation. According to our research, the inferior division supplies the temporal, temporo-occipital, and angular regions, whereas the superior division supplies the frontal and parietal regions.MCA is the most commonly treated cerebral artery using mechanical thrombectomy .knowledge of MCA diameter, length of M1, branching pattern, trunk dominance, take of lenticulostriate artery and cortical branches essential to treat MCA thrombus. A study by *R khatri et al* in[7] published in 2019 suggest that the operator performing Mechanical Thrombectomy should be aware to MCA anatomy to remain in true lumen of MCA and also avoid injury to Lenticulostriate artery .

5. **Tumours around sylvian fissure and skull base lesion** :

Gliomas are commonly located in insular region.[5]Tumours around sylvian fissure and on skull base can involve MCA and its branches. While removal of these tumour the anatomical knowledge of MCA are very useful to avoid post op neurological deficit. Also many times it require a STA-MCA bypass to avoid hemispheric infarct.

Limitation of this study were that the specimens were formalin fixed so while dissecting MCA some perforators were injured also formalin fixed vessels were more shirnked and rigid compared to fresh cadavers. Small sample size of our study is also a shortcoming of this study.

CONCLUSION

Documentation of micro surgical anatomy of the cerebral vasculature is not common in Indian literature. Only a few studies were present on microsurgical anatomy of MCA. The results of these studies were not uniform showing variations in MCA anatomy Knowledge of the micro surgical anatomy of the cerebral vasculature is essential for a neurosurgeon operating upon cerebrovascular disorders. MCA had many variations along its course .We found The longer M1 segment, different perforators origins , their number and multiple branching pattern of MCA in our study compared to many other studies suggest that MCA had geographical variations. The knowledge of these variations are very useful while doing many neurosurgical procedures. Micro surgical cadaveric dissection not only achieves this but also enhances the confidence levels of the neurosurgeon. Cadaveric studies/research should be done regularly. So we recommend that Cadaveric dissection programme should be integrated in neurosurgical training programme to enhance the knowledge in neurosurgical anatomy.

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ANNEXURE -1

Declaration by the Student

I hereby declare that:

1. The study will be done as per ICMR/ GCP guidelines.
2. The study has not been initiated and shall be initiated only after ethical clearance
3. Voluntary written consent of the volunteers/ patients will be obtained.
4. In case of children or mentally handicapped volunteers/patients, voluntary written informed consent of the parents/ guardians will be obtained.
5. The probable risks involved in the study will be explained in full to the subjects/ parents/ guardians in their own language.
6. Volunteers/ patients/ parents/ guardians will be at liberty to opt out of the study at any time without assigning reason.
7. I will terminate the study at any stage, if I have probable cause to believe, in the exercise of the good faith, skill and careful judgement required for me that continuation of the study/ experiment is likely to result in injury/ disability/ death to the volunteers/subject.

Date

Signature of student
Department

Signature of guide
Department

ANNEXURE -2

Observation chart

Microsurgical anatomy of MCA.

OBSERVATIONS:

1. ICA – OD:
2. MCA-OD:
3. ACA-OD:
4. MCA- Length
5. Early branches:
6. Accessory MCA:
7. Perforators:

   M1 Perforators:

   Proximal:

   Distal:
8. M1 division: Bifurcation / Trifurcation / Multiple
9. Early cortical branches
10. Shortest cortical branch
11. Longest cortical branch

ANNEXURE -3

Ethical Clearance Certificate

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर

All India Institute of Medical Sciences, Jodhpur

संस्थागत नैतिकता समिति

Institutional Ethics Committee

No. AIIMS/IEC/2021/ 3542 **Date: 12/03/2021**

ETHICAL CLEARANCE CERTIFICATE

Certificate Reference Number: **AIIMS/IEC/2021/3377**

Project title: **"Study of microsurgical anatomy of middle cerebral artery in human cadaveric brain"**

Nature of Project:	**Research Project Submitted for Expedited Review**
Submitted as:	**M.Ch. Dissertation**
Student Name:	**Dr. Vishnu Gupta**
Guide:	**Dr. Deepak Kumar Jha**
Co-Guide:	**Dr. Surajit Ghatak, Dr. Shilpi Gupta Dixit, Dr. Ashish Kumar Nayyar & Dr. Jaskaran Singh Gosal**

Institutional Ethics Committee after thorough consideration accorded its approval on above project.

The investigator may therefore commence the research from the date of this certificate, using the reference number indicated above.

Please note that the AIIMS IEC must be informed immediately of:

- Any material change in the conditions or undertakings mentioned in the document.
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research.

The Principal Investigator must report to the AIIMS IEC in the prescribed format, where applicable, bi-annually, and at the end of the project, in respect of ethical compliance.

AIIMS IEC retains the right to withdraw or amend this if:

- Any unethical principle or practices are revealed or suspected
- Relevant information has been withheld or misrepresented

AIIMS IEC shall have an access to any information or data at any time during the course or after completion of the project.

Please Note that this approval will be rectified whenever it is possible to hold a meeting in person of the Institutional Ethics Committee. It is possible that the PI may be asked to give more clarifications or the Institutional Ethics Committee may withhold the project. The Institutional Ethics Committee is adopting this procedure due to COVID-19 (Corona Virus) situation.

If the Institutional Ethics Committee does not get back to you, this means your project has been cleared by the IEC.

On behalf of Ethics Committee, I wish you success in your research.

Dr. Praveen Sharma
Member Secretary

Member secretary
Institutional Ethics Committee
AIIMS,Jodhpur

Basni Phase-2, Jodhpur, Rajasthan-342005; **Website:** www.aiimsjodhpur.edu.in; **Phone:** 0291-2740741 Extn. 3109
E-mail : ethicscommittee@aiimsjodhpur.edu.in; ethicscommitteeaiimsjdh@gmail.com

ANNEXURE -4

<u>Master Chart</u>

S.No.	MCA OD (mm)	ICA OD (mm)	M1 length (mm)	Branching pattern	Trunk dominance	PrB Perforators	Pob Perforators	ECB	Shortest cortcile artery	Longest cortical artery
Sample 1	3.68	4.1	19.8	B	Superior	12	**3**	1	**TPo**	**PPA**
Sample 2	3.94	4.0	26.6	B	Superior	11	1	2	TPo	PPA
Sample 3	5.4	4.98	28.8	Q	Inferior	8	2	1	TPo	AngA
Sample 4	2.8	2.9	22.2	B	Inferior	7	2	1	OFA	TOA
Sample 5	2.7	3.0	27.8	T	Middle	10	3	1	TPo	AngA
Sample 6	3.5	3.8	33.8	B	Inferior	8	2	1	TPo	PPA
Sample 7	2.7	2.9	22.9	B	Inferior	11	3	1	OFA	AngA
Sample 8	2.9	3.1.1`	20.9	B	Inferior	3	5	1	TPo	PPA
Sample 9	3.7	3.8	27.2	Q	Inferior	11	2	2	TPo	TOA
Sample 10	2.7	3.5	18.6	T	Inferior	6	3	3	TPo	TOA
Sample 11	4.5	4.8	22.5	B	Equal	8	4	2	OFA	PPA
Sample 12	2.4	3	15.7	B	superior	9	7	1	OFA	PPA
Sample 13	2.8	4	16.7	B	Equal	5	6	2	TPo	AngA
Sample 14	2.9	3.2	30.3	T	Inferior	11	2	02	TPo	AngA
Sample 15	3.2	3.6	21.4	B	superior	10	2	1	OFA	TOA

Sample 16	3.3	4.0	23.5	B	equal	7	3	3	OFA	PPA
Sample 17	2.9	3.0	23.7	B	Inferior	9	2	2	TPo	PPA
Sample 18	3.8	4.0	28.2	T	superior	13	3	1	TPo	PPA
Sample 19	3.6	4.1	20.8	B	Superior	8	3	3	TPo	TOA
Sample 20	2.3	2.5	33.2	M	equal	14	0	2	OFA	AngA
Sample 21	2.9	3.1.1`	20.9	B	Inferior	7	6	1	TPo	PPA
Sample 22	3.7	3.8	27.3	Q	Inferior	9	2	2	TPo	TOA
Sample 23	2.7	3.5	18.5	T	Inferior	11	3	3	TPo	TOA
Sample 24	4.5	4.8	22.3	B	Equal	8	4	2	OFA	PPA
Sample 25	2.4	3	16.1	Q	superior	9	7	1	OFA	PPA
Sample 26	2.8	4	16.9	B	inferior	4	2	3	TPo	AngA
Sample 27	2.7	3.0	30.2	T	Middle	12	3	1	TPo	AngA
Sample 28	3.5	3.8	33.8	B	Inferior	7	3	1	TPo	PPA
Sample 29	2.7	2.9	22.9	Q	Inferior	11	2	1	OFA	AngA
Sample 30	2.9	3.1.1`	21.1	B	superior	10	1	1	TPo	PPA
Sample 31	3.7	3.8	33.2	M	Inferior	6	2	2	TPo	TOA
Sample 32	2.7	3.5	18.9	B	Inferior	12	3	3	TPo	TOA

(B- Bifurcation, T – Trifurcation, Q- Tetrafurcation , M- Monofurcation, TPo- Temporo-polar artery, OFA- orbitofrontal artery, PPA- Posterior Parietal artery, TOA- Temporo occipital artery, Ang A- Angular artery,