

Original Article

A study of the orbitofrontal branch of the middle cerebral artery in Northern India

Medha Das^{a,*}, Pranjal Pankaj^b, Shirin Jahan^a, R.K. Shrivastava^a^a Dept of Anatomy, Rama Medical College, Mandhana, Kanpur, India^b Dept of Medicine, Rama Medical College, Mandhana, Kanpur, India

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ABSTRACT

Introduction: The orbitofrontal branch of the middle cerebral artery (MCA) is responsible for blood supply to the orbitofrontal cortex along with the orbitofrontal branch of the anterior cerebral artery. Mostly, it is a branch of superior division of M2 segment of MCA; however, in this study, it was seen to arise more commonly from M1 segment of MCA. Though the orbitofrontal branch of ACA is researched by many authors, the orbitofrontal branch of MCA has gained less attention of the researchers. There is paucity of work on this branch of MCA in Indian literature specially in the northern part. Descriptions of the orbitofrontal branch of the middle cerebral artery, which we found in the literature, did not correlate with our observations. The aim of the study was to observe, record, and compare variations in origin and branching pattern of the orbitofrontal artery, hoping to find immediate application of our findings in the field of cerebrovascular surgery.

Materials and methods: A total of 20 middle cerebral arteries were studied, which were obtained from 10 brains. Meticulous dissection was done, and the middle cerebral artery was exposed and cleaned in lateral sulcus on the inferior surface of the brain. Its orbitofrontal branch was studied in detail. Digital photographs were taken.

Result: Out of the 20 MCAs studied, the orbitofrontal artery was found to arise from M1 segment in 15 cases. In the remaining 5 cases, it was found to originate from the superior trunk of M2 segment of the middle cerebral artery.

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1. Introduction

The *middle cerebral artery* (MCA) is one of the three major paired arteries that supplies blood to the cerebrum. The MCA arises from the internal carotid as the larger terminal branch. At first, it runs in the lateral fissure, then posterosuperiorly on the insula, and divides into branches distributed to the insula and the adjacent lateral cerebral surface. It also supplies blood to the anterior temporal lobes and the insular cortices.¹

It can be divided into the following four segments:²

- M1 segment, running horizontally in the sylvian fissure.
- M2 segment, running vertically on the surface of the insula.
- M3 segment, running laterally and exiting the insular cistern.

- M4 segment, which comprises the distal cortical branches.

The orbitofrontal artery is one of the cortical branches that divide into the frontal and orbital branches to supply to the lateral orbital gyri and part of middle and inferior frontal gyri. It infrequently arises from M1 segment of MCA; more frequently, it is reported to be a branch of the superior division of MCA (M2 segment). The orbitofrontal artery is the first branch to leave the sylvian insular cistern. It runs anteriorly, with a slight horizontal course, toward the pars orbitalis of the inferior frontal gyrus. It is in balance with the fronto-orbital branch of the anterior cerebral artery (ACA).

The M1 segment arises at the internal carotid bifurcation (ICA) and runs horizontally and laterally in the sylvian fissure below the anterior perforated substance toward the insula. It is also known as the sphenoidal segment because it runs parallel and posterior to the sphenoid ridge. The M1 segment ends at the limen insulae, where it turns superiorly and posteriorly to reach the surface of insula, to form the M2 segment. The M1 divides distally into two or

* Corresponding author at: Department of Anatomy, Rama Medical College Hospital & Research Institute, Mandhana, Kanpur 209217, India.

E-mail address: drmedhadas@rediffmail.com (M. Das).

sometimes three divisions (bifurcation or trifurcation).³ In case of bifurcation, the divisions are superior and inferior trunks. In case of trifurcation, the additional division is middle trunk. The M1 segment gives two types of branches – perforators and cortical branches.

The branches of the MCA supplying the frontal lobe can be described as follows:^{4,5}

- Orbitofrontal artery (OBFA, also known as lateral frontobasal artery): This branches out anteriorly, superiorly, and laterally to vascularize the inferior frontal gyrus. This competes in size with the frontal polar branch of the anterior cerebral artery.
- Prefrontal artery (PFA): This artery fans out over the insula and exits to the cortex via the medial surface of the frontal operculum. The artery fans superiorly over the pars triangularis and vascularizes the inferior and middle frontal gyri. Near the superior frontal gyrus, the artery anastomoses with branches from the pericallosal branch of the anterior cerebral artery.
- Prerolandic artery (precentral or PCA): The artery extends out on the medial surface of the operculum and supplies the posterior parts of the middle and inferior frontal gyri as well as the lower parts of the precentral gyrus. This artery branches once or twice and is relatively invariant across anatomies.
- Rolandic artery (central artery or CA): The artery extends out and exits from the central portion of the operculum, and then passes inside the central sulcus. This artery bifurcates in 72% of the individuals and irrigates the posterior precentral gyrus and the inferior portion of the postcentral gyrus.

2. Materials and methods

This work was carried out in the Department of Anatomy, RIMS, Ranchi and continued in Rama Medical College, Kanpur. The middle cerebral artery was observed in the brain obtained from cadavers donated for routine educational dissection. Totally, 20 MCAs, obtained from 10 brains, were studied.

The brain was removed by the dissection method mentioned in the Cunningham Manual of Practical Anatomy.⁶ After removal of the brain from the skull, blood vessels on the base of the brain were cleaned from piamater on the external surface of which it lies. Through meticulous dissection, the middle cerebral artery was cleaned and variation in origin and branching pattern of the orbitofrontal branch was observed. Digital photographs were taken. The results obtained were recorded and tabulated.

The study was approved by the Ethical Committee of RIMS, Ranchi and RMCHRC, Kanpur.

Inclusion criteria – Undamaged specimens of the brain with intact middle cerebral artery.

Exclusion criteria – Brain specimen with damaged middle cerebral artery.

3. Results

In all the cadavers, the middle cerebral artery originated from ICA as the larger terminal branch opposite the optic chiasma. Out of the 20 MCAs studied, the orbitofrontal artery was found to arise from M1 segment in 75% of the specimens (15 out of 20 cases). In the remaining 25% (5 out of 20 cases), it was found to originate from the superior trunk of M2 segment (Table 1). Most of the times, it was found that after origin from the M1 segment, it passes anterolaterally to the lateral part of orbital surface of the frontal lobe where it divided into the frontal and orbital branches to supply to the lateral orbital gyri and part of middle and inferior frontal gyri.

In 20% of the specimens (4 out of 20) where the orbitofrontal artery was taking origin from M1 segment, it was the first cortical

Table 1

Origin of orbitofrontal artery (OBF) from middle cerebral artery (MCA).

Segment of origin of OBF artery from MCA	No. of specimens	Percentage
M1 segment	15	75
Superior division of M2 segment	5	25

Table 2

Pattern of origin of OBF from M1 segment of MCA.

	No. of specimens	Percentage (out of 20)
As first branch from M1 segment	4	20
As second branch from M1 segment	11	55

branch from M1 segment (Fig. 1). This case was found in two brains bilaterally, where it divided into the frontal and orbital branches to supply to the lateral orbital gyri and part of middle and inferior frontal gyri (Table 2).

In one of these two brains, on the right side, OBF artery was the thick, first branch from M1 segment, which first gave the orbital branch, then after a short course laterally gave the frontal branch, and continued over the insula to give the prefrontal artery (Fig. 2). In the same brain on the left side, OBF artery and prefrontal artery were seen to take origin from M1 segment side-by-side, with OBF being the first branch, and giving appearance of early division of MCA (early pseudotrifurcation) (Fig. 3).

In the remaining 55% of specimens (11 out of 20), the orbitofrontal artery was the second branch from M1 segment of MCA, with a temporal branch being the first. This situation was found in 5 brains bilaterally. In one specimen, the stem of origin of OBF artery from M1 segment (2nd branch) was very thick, giving an appearance of early division of MCA (early pseudobifurcation, Fig. 4). In this case, OBF artery stem was 1.2 cm long, which divided anteriorly into the orbital and frontal branches, which again were thicker than usual.

In one brain, OBF artery was taking origin from M1 segment on the left side as second branch, whereas on the right side, it was taking origin from the superior division (M2 segment) of MCA; in addition to giving the orbital and frontal branches, it also gave the prefrontal artery on the left side, which usually takes origin separately from the superior division (Figs. 5–7).

In 4 out of the 5 cases where OBF artery was found to be a branch of the superior division of MCA (M2 segment), it was a bilateral presentation found in two brains. In one brain on the right side, the origin of OBF artery was from the superior division of MCA, whereas on the left side, it was a branch of M1 segment.

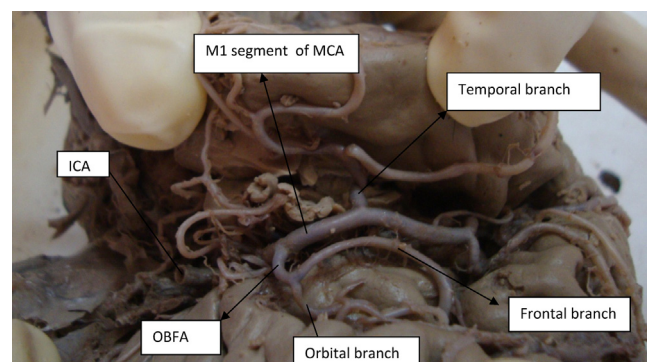


Fig. 1. Origin of orbitofrontal artery (OBFA) from M1 segment of the middle cerebral artery (MCA) as the first cortical branch. ICA = internal carotid artery.

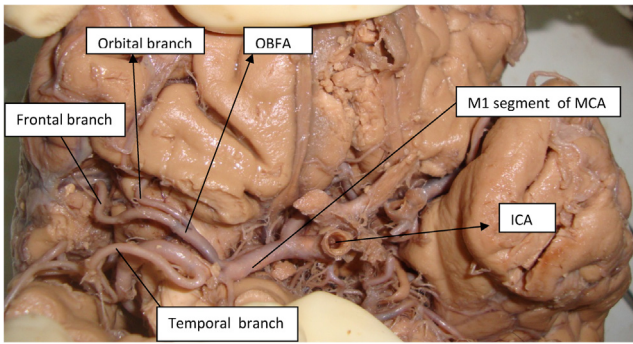


Fig. 2. Thick OBFA (orbitofrontal artery) from M1 segment as 1st cortical branch giving the orbital and frontal branches separately and then continuing over insula. ICA = internal carotid artery, MCA = middle cerebral artery.

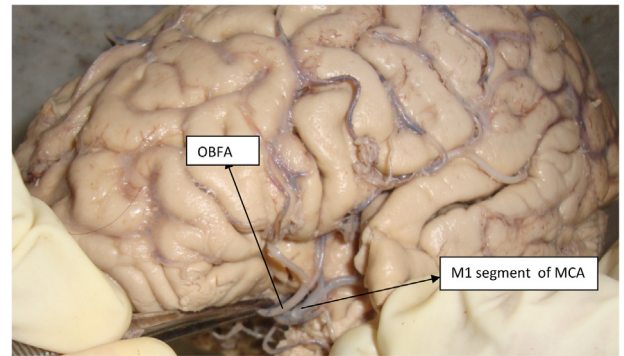


Fig. 5. Origin of OBFA (orbitofrontal artery) from M1 segment of MCA (middle cerebral artery) on the left side.

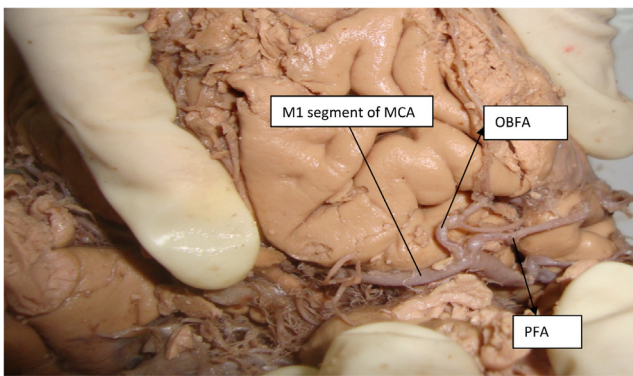


Fig. 3. OBFA (orbitofrontal artery) and prefrontal artery (PFA) taking origin from M1 segment of MCA (middle cerebral artery) side-by-side (early pseudotrifurcation).

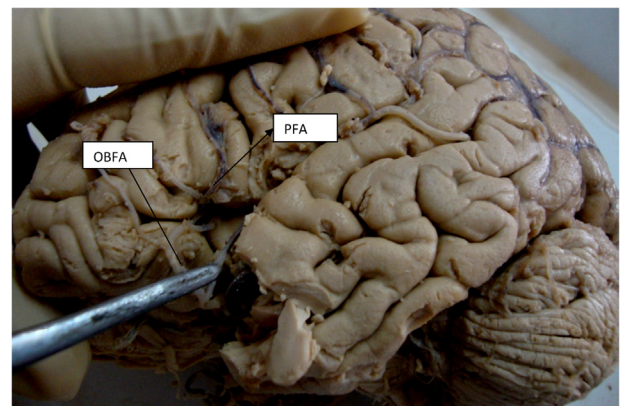


Fig. 6. Origin of prefrontal artery (PFA) from OBFA (orbitofrontal artery) in the same brain.

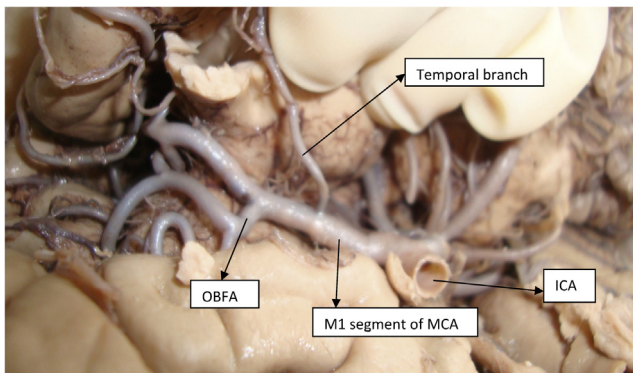


Fig. 4. Origin of thick OBFA (orbitofrontal artery) from M1 segment of MCA (middle cerebral artery) as second cortical branch (pseudoeary bifurcation).

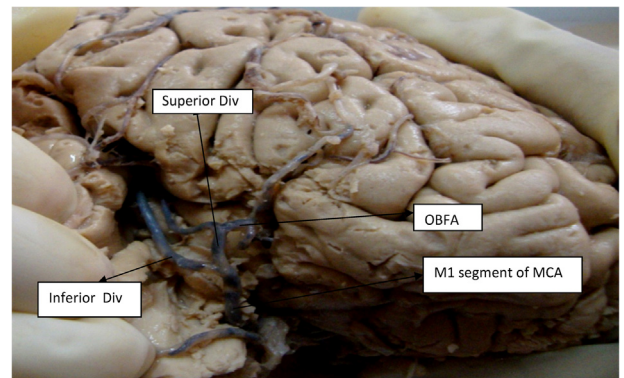


Fig. 7. Origin of OBFA (orbitofrontal artery) from the superior division (M2 segment) of MCA on the right side in the same brain.

The orbitofrontal artery in addition to giving the orbital and frontal branches also gave rise to other branches, which are usually branches of the superior trunk. They were the precentral artery and the prefrontal artery. The prefrontal artery was seen to originate from OBF in 5 cases while it originated from OBFA in one case.

Out of the 5 cases where the prefrontal artery was taking origin from OBFA, four cases were present in two brain bilaterally. In one brain, OBFA was taking origin from M1 segment bilaterally, which also gave the prefrontal artery on both sides (Fig. 6). In another brain, OBFA was taking origin from the superior trunk of MCA (M2 segment) bilaterally, which also gave the prefrontal artery (Fig. 9).

In one brain, on the left side, OBFA was very thick, taking origin from M1 segment as a second branch, which after giving the orbital branch continued and gave prefrontal and precentral arteries. In this case, the central artery was originating from the superior trunk (Fig. 8).

4. Discussion

The middle cerebral artery supplies to the largest area of the cerebral hemispheres and has most complex branching among the intracerebral vessels. The orbitofrontal artery is one of the cortical branches that divides into the orbital (lateral orbital frontal artery, LOFA) and frontal branches to supply the lateral orbital gyrus and

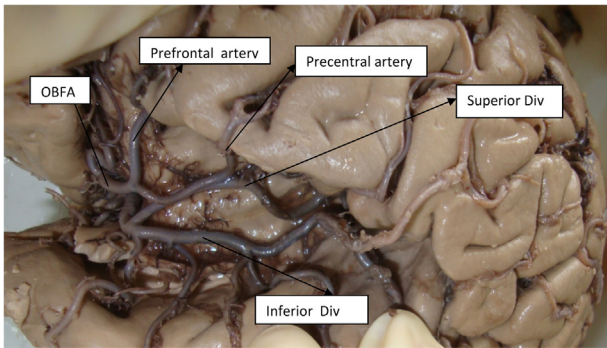


Fig. 8. Origin of prefrontal and precentral artery from OBFA (branch of M1 segment of MCA in this case). OBFA = orbitofrontal artery.

part of middle and inferior frontal gyri, respectively. The lateral orbitofrontal artery along with medial orbitofrontal artery (MOFA), which is a branch of anterior cerebral artery, supplies to the orbitofrontal cortex.

Though there is plenty of works on other cortical branches of MCA, relatively few researchers have focused on OBFA. The variation in the origin of OBFA in Indian population, specially in the northern part, is unexplored yet.

Yasargil described the origin of LOFA from the superior trunk of the MCA as a separate branch, or from a common trunk with the prefrontal and lateral striate arteries.⁷ The anatomy of the middle cerebral artery, in relation to occlusion of its branches, was described in detail by Foix and Levy in 1927 just prior to the introduction of cerebral angiography.⁸

Moniz (1940) preferred to designate the entire middle cerebral artery system as the Sylvian group. The commonly accepted nomenclature at that time was that of four main branches of the middle cerebral artery, exclusive of the lenticulostriate arteries, these being the ascending frontal, otherwise known as the 'candelabra group' or the ascending frontal parietal, the posterior parietal, angular, and posterior temporal. The primary differences between this classification and that of anatomists are in the nomenclature of the ascending frontal artery, the branches of which were given individual names by the original investigators.⁹

Greitz and Lindgren (1961) describe the four vessels as commonly arising proximally from the main trunk of the middle cerebral artery, while Peel (1954) depicts one main trunk distal to the origin of the ascending frontal that breaks up into the three remaining branches.^{10,11}

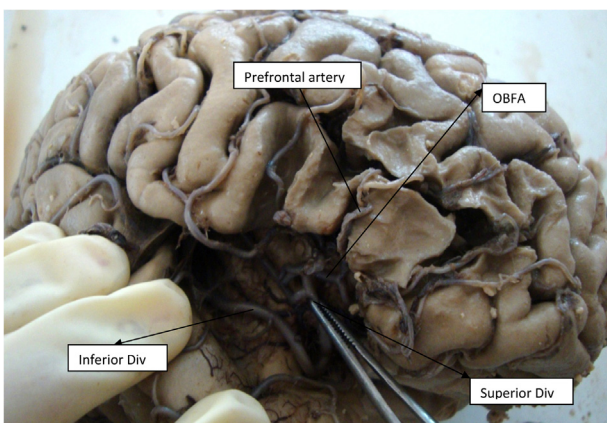


Fig. 9. Origin of prefrontal artery from OBFA (branch of superior division of M2 segment of MCA in this case). OBFA = orbitofrontal artery.

Ecker (1951) states that there are usually 2 or 3 main trunks in the Sylvian fissure. Other opinions are summarized by Pendercraes et al. (1956) in their text.^{12,13}

Ring (1962) studied the branching pattern of middle cerebral artery in 75 brain specimens. Out of these 75, study on 25 brains was dissection based. He stated the middle cerebral artery as the most complex of the major intracerebral arteries, and the ascending frontal as the most complex of its branches. He stated that the complexity of this vessel is due to its large size and numerous branches and partly to the anatomy of the area, since vessels passing up the medial aspect of the Sylvian fissure are infolded with the insula so they appear to loop upon themselves. The term 'candelabra group' comes from the shape of the major branches making up the complex. The orbitofrontal was described as a branch of the ascending frontal artery that was easily recognizable on brain specimens but were seldom prominent on angiograms. In the brain specimens, it was not uncommon to find the complex made of two vessels instead of a single main trunk, but the extra vessel had no constant relationship. The ascending frontal artery may arise from a branch that appears to be the main trunk of the posterior temporal, angular, or posterior parietal artery.¹⁴

Lima is one of the few in the radiographic field to attempt to subdivide the branches of this vessel for practical diagnostic purposes. He describes three parts of the ascending frontal artery – the orbitofrontal branches, running on the orbital surface of the frontal lobe, the inferior frontal, and the prerolandic.¹⁵

Tanriover (2003) describes that the LOFA usually arises from an early frontal branch of MCA and supplies to the lateral orbitofrontal cortex. Early branches that arose more proximally from the M1 segment were larger than those arising distally. Lenticulostriate arteries arose from 81% of the early frontal branches (EFBs).¹⁶

In 2005, Pai and Varma did a dissection-based study on the microsurgical anatomy of the MCA. They reported origin of the orbitofrontal artery from the superior division of MCA (M2 segment) in 7 specimens out of 10 (70%). In the remaining 3 specimens, OBFA was originating from M1 segment of MCA (30%). However, in our study, the origin of OBFA was observed from M1 segment in 75% of the specimens, which is significantly more than that reported by Pai et al.¹⁷

5. Conclusion

The orbitofrontal cortex is important for the surgery of the anterior circulation aneurysms and frontal lobe tumors. It contains the secondary taste cortex, and the secondary and the tertiary olfactory cortical areas. This region is involved in associational functions related to emotion, cognition, rewards and punishments, and personality. It is involved in learning and in reversing stimulus-reinforcement associations. Damage to the orbitofrontal cortex impairs the learning and reversal of stimulus-reinforcement associations. It can also impair face expression identification. To achieve an optimal outcome after tumor or aneurysm surgery, precise knowledge of the arterial supply of the orbitofrontal cortex is mandatory.

The vascular supply of the orbitofrontal cortex is provided mainly by the orbitofrontal arteries, which are the branches of the anterior cerebral artery (ACA) and middle cerebral artery (MCA). The orbitofrontal arteries supply the sulci of the orbitofrontal cortex and give rise to many perforators.

Although the orbitofrontal branch of anterior cerebral artery (medial frontobasal artery) is studied by many authors, the orbitofrontal branch of middle cerebral artery has interested few. Descriptions of the orbitofrontal branch of middle cerebral artery, which we found in the literature, did not correlate with our observation. We undertook this study to define further the

variations in origin of OBFA hoping to find immediate application of our findings in the field of cerebrovascular surgery, as the knowledge about the artery and its early branches is fundamental for planning and undertaking the surgery in this region.

Conflicts of interest

The authors have none to declare.

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