Section: Anatomy

Original Research Article

A STUDY ON THE VARIATIONS IN THE BRANCHING PATTERN OF ANTERIOR CEREBRAL ARTERY AND ITS CLINICAL SIGNIFICANCE

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Abstract

Background: Anterior cerebral artery which is paired is one of the terminal branches of internal carotid arteries. It forms the anterior part of Circle of Willis. Through its various branches it provides blood supply to medial surface of brain. This study was done to note the anatomical pattern and variations of anterior cerebral arteries in human cadavers. **Materials and Methods:** Fifty embalmed adult human brain specimens were used for the study in the Institute of Anatomy, Madurai Medical College, Madurai. The origin, course and branches of anterior cerebral artery were noted and compared with previous studies. **Result:** The anterior cerebral artery took its origin from the corresponding internal carotid artery at the anterior perforated substance and was single in number at its origin. The angulations of the artery towards the anterior communicating artery varied from 50 to 60 degrees in all the specimens. Length and diameter of A1 segment was within the normal limit so that no hypoplastic changes were seen. The perforators arising from this segment were a maximum of 4 in number. Diameter of A2 segment was within normal limit. No hypoplastic or aplastic changes occurred. The three branches constantly seen in the entire specimen are the orbitofrontal, frontopolar and callosomarginal artery. **Conclusion:** Knowledge of branching pattern and area of distribution of anterior cerebral artery is of prime importance in diagnosing the clinical condition which varies depending upon the location and distribution of the lesion.

INTRODUCTION

Anterior cerebral artery is one of the terminal branches of internal carotid artery. From the anterior perforated substance it is directed at first medially above the optic nerve. It enters the median longitudinal fissure of brain and connects with the corresponding artery of the opposite side through anterior communicating artery. Then it reaches medial surface of brain in conformity with the curvature of the outer surface of corpus callosum .Finally it runs upwards just in front of parieto-occipital sulcus. The anterior cerebral artery gives off the following branches-medial striate, orbital, fronto-polar, calloso-marginal and pericallosal. The areas distributed by the branches of anterior cerebral arteries are medial part of orbital surface, corpus callosum, medial surface of frontal and parietal lobes and a strip of cortex on the supero-medial border of the hemisphere.[1] With the advent of advanced techniques in micro neurosurgery and with the evolution of sophisticated diagnostic procedures, cerebrovascular lesions gain much importance in modern days. So a thorough knowledge of the cerebral arteries, its distribution to the cortical functional areas and its distribution through perforating arteries, is of prime importance. In order to add some more to the present available details, a study and discussion of the anterior cerebral artery gains significance.

MATERIALS AND METHODS

Fifty brain specimens were collected from the embalmed cadavers in the Institute of Anatomy, Madurai Medical College, Madurai. The present study was carried out irrespective of age, sex and socio economic status. The specimens were collected from the subjects who had died of natural causes. Those cases with remarkable alterations of the brain or evidencing gross pathological lesions like crushed injuries, macroscopically identified cortical tumors, severe hemorrhages or infections were excluded. The specimens were preserved in 10% formalin solution and numbered serially from 1 to 50 for the study.

The inferior surface of the brain was viewed and the internal carotid artery was identified. The origin of anterior cerebral artery from the internal carotid artery and the anterior communicating artery uniting the two anterior cerebral arteries were traced. The two hemispheres were separated at the longitudinal fissure by a midline incision through the corpus callosum and allowed to fall apart to view the medial surface. Further course of the anterior cerebral artery in front of the genu and above the body of the corpus callosum and ending near its posterior part were identified.[2] The site and origin of the anterior cerebral artery was noted. The length and the external diameter of the A1 segment were measured. A caliper graduated to measure up to 0.1mm was used for the measurement of diameter. The origin of the Heubner's artery, Perforators, orbitofrontal, frontopolar, callosomarginal artery, pericallosal artery, medial rolandic artery and its encroachment to superior border and superolateral surface, medial prerolandic artery, and posterior parietal arteries were studied. The presence of azygos anterior cerebral arteries, fenestration and aneurysm were looked for. Photographs were taken almost perpendicular to the plane of the arteries in order to avoid errors due to different angles of view. The variations of the anterior cerebral artery were compared with the previous studies.

RESULTS

In all the 50 specimens dissected the anterior cerebral artery was branching from the corresponding internal carotid artery. On both sides only one anterior cerebral artery was seen from each internal carotid artery at the anterior perforated substance and passed over the optic nerve. The length of the A1 segment was in the range of 11mm to 17mm with a mean length of 14.8mm on right and 14.7 mm on the left side [Figure 1]. The outer diameter of the anterior cerebral artery on both sides was ranging from 1.5 to 3.2mm with a mean of 2.51mm on the right and 2.6mm on the left side [Figure 2]. On its course towards the anterior communicating artery, the anterior cerebral artery took an anteromedial course at an angulation varying from 50 to 60 degrees to the anteroposterior plane. There was no difference in angulation between the two sides [Figure 3].

It has been noted that these perforators arose from the postero inferior and postero superior surface of A1 segments of the anterior cerebral artery [Figure 4]. These were generally very small twigs and few in number and situated more medially than laterally. On the right side fifteen specimens had one perforator, twenty-five had two perforators. On the left side sixteen had one perforator, twenty-six had two perforators. Three perforators arose in eight specimens on both the sides and also a maximum of four perforators took origin in two specimens only on the right side. The portion of the anterior cerebral artery distal to the anterior communicating artery is referred to as the distal anterior cerebral artery or A2 segment. The A2 diameter was in the range of 2mm to 3.5mm on both sides with a mean of 2.5mm on the right and 2.5mm on left side [Figure 5]. In forty seven cases both the A2 segments were of equal diameter and in three cases right A2 was larger. The A2 segments hardly gave rise to any perforators apart from the recurrent arteries. The cortical branches that were seen constantly in all specimens were the orbitofrontal, frontopolar and callosomarginal arteries. The callosomarginal artery was seen to arise at the level of the genu of the corpus callosum in all cases except one in which it arose proximal to the genu. After giving the fronto polar branch it ended by dividing into three branches [Figure 6]. Usually the A2 segment distal to the callosomarginal artery continued as the pericallosal artery which ran posteriorly over the corpus collosum. In one specimen an interhemispheric branch arising from the A2 segment on the right side continued as the pericallosal artery on the left side [Figure 7]. The posterior parietal artery on the left side originated from the crossed pericallosal artery [Figure 8]. The medial rolandic branch was found in thirty cases, medial prerolandic was found in five cases and posterior parietal branches were found in eleven cases.

The A2 segments gave branches to both sides of the hemisphere in four cases. In all these four cases the inter hemispheric branches were given of from right to left side and consequently the diameter of the right A2 segment in these four specimens were larger than the left side.

In Specimen No:12 on the right side the frontopolar, callosomarginal, medial rolandic, pericallosal artery were seen in the normal pattern while on the left side the frontopolar and callosomarginal arose from the same side of A2 segment and the pericallosal artery continued from an inter hemispheric branch.

In Specimen No: 13 the A2 segments from both sides were passing only on the right side above the corpus callosum. One of the A2 segment provided five inter hemispheric branches which crossed to the left side of cerebral hemisphere [Figure 9]. This inter hemispheric branches provided the frontopolar callosomarginal and pericallosal artery on the left side. Again a third branch was arising at the level of anterior communicating artery running upwards along with the other two A2 segments above the genu of the corpus callosum, followed the course in the same manner and ended by turning upwards similar to the callosomarginal artery on the right side [Figure 10].

In Specimen No: 23 the branching pattern on the right side are normal. On the left side only the fronto polar was seen to be coming from the left A2 segment. The remaining branches namely callosomarginal, medial rolandic, posterior parietal and pericallosal arteries arose from an inter-hemispheric branch of the right side. The branches of the A2 segment had an encroachment over the superomedial border to run in

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the supero lateral surfaces of the cerebral hemispheres [Figure 11].

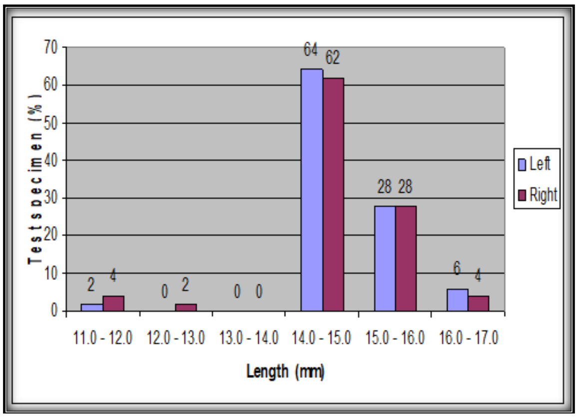

Figure 1: Length of A1 segment

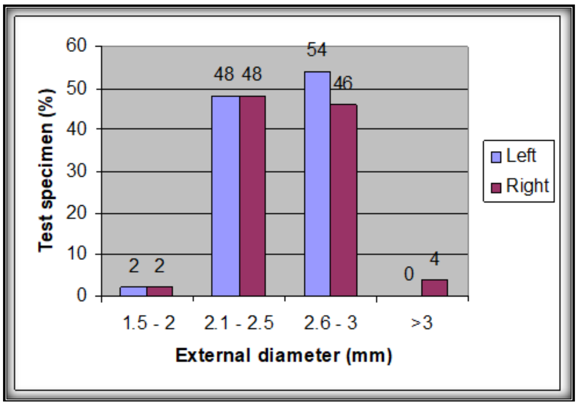

Figure 2: Outer diameter of A1 segment at its origin

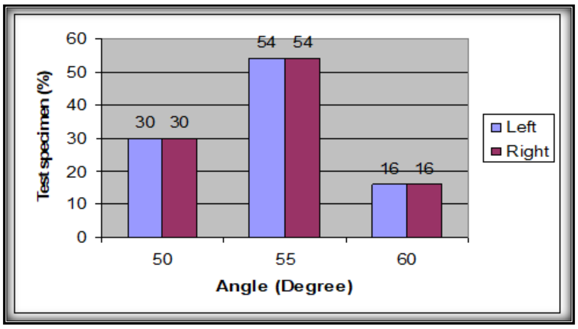

Figure 3: Angulations of A1 segment

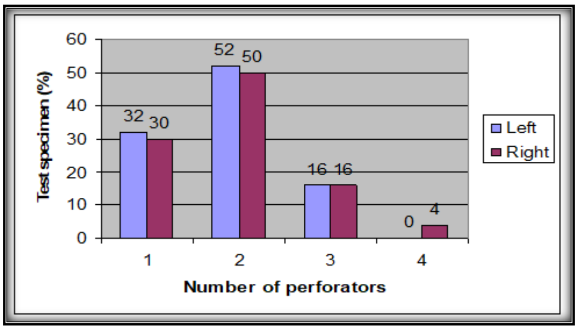

Figure 4: Branches from A1 segment- perforators

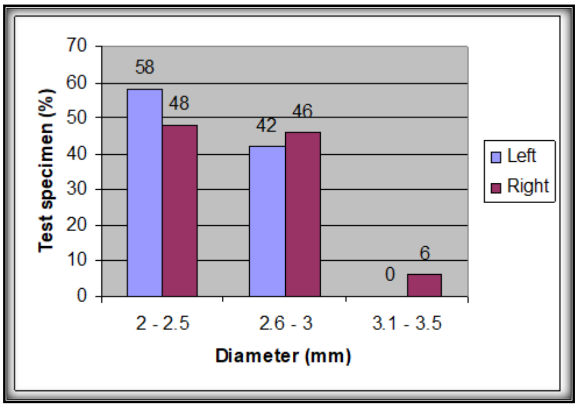

Figure 5: Diameter of the distal anterior cerebral artery

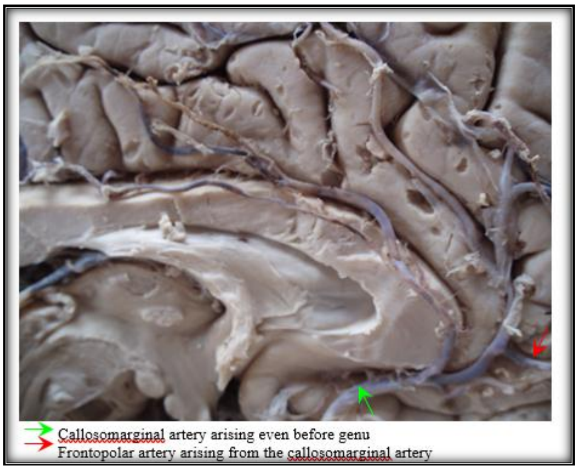

Figure 6: Variation in Callosomarginal artery

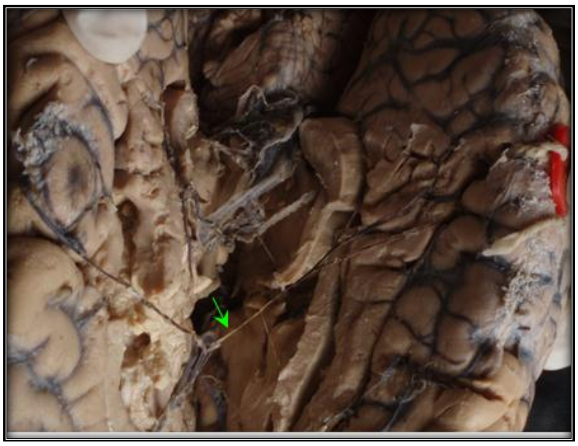

Figure 7: Image of a left pericallosal artery arising from right A2 segment

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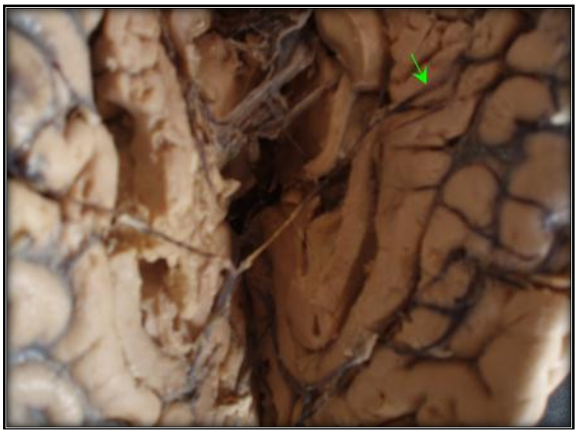

Figure 8: View of left posterior parietal artery arising from the crossed pericallosal artery

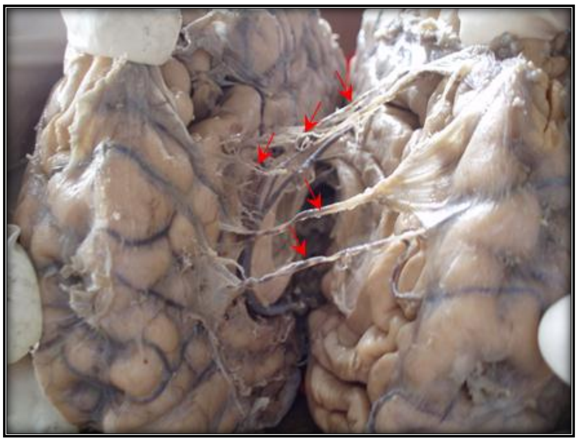

Figure 9: View of five interhemispheric branches from right to left

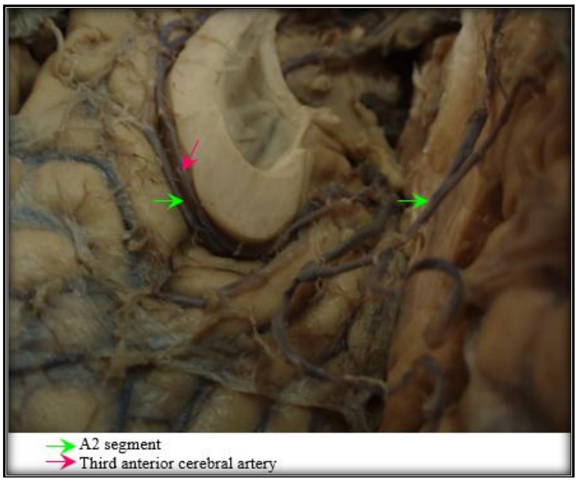

Figure 10: Illustration of a third anterior cerebral artery

Figure 11: Callosomarginal and medial Rolandic branches encroaching with the superomedial border and superolateral surface

DISCUSSION

The internal carotid artery terminates by dividing into the anterior cerebral artery and the middle cerebral artery at the level of anterior perforated substance. G.J.Romanes noted that anterior cerebral artery arise from its fellow by enlargement of the anterior communicating artery.[2] Chummy S.Sinnatamby referred that both anterior cerebral arteries may arise from one internal carotid artery as a common stem.[3] The anterior cerebral artery courses anteromedially to cross over the optic nerve and the optic chiasma to communicate with opposite anterior cerebral artery through the anterior communicating artery. This segment from origin to the anterior communicating artery was considered as A1 segment and distal to anterior communicating artery was A2 segment.[4] Standard text books, Gray's Anatomy and Last's Anatomy describe the origin of the anterior cerebral artery from the internal carotid artery at the anterior perforated substance. In the present study the site of origin was in accordance with the texts. Regarding the frequency only one artery took origin from each internal carotid artery. It was observed that the anterior cerebral artery contributes for the formation of circle of Wills anterolaterally and courses anteromedially to cross over the optic nerve and optic chiasma to communicate with the opposite anterior cerebral artery through the anterior communicating artery.

SB Pai et al noted the angulation ranged from 45 to 60 degree and in two cases it was 80 degrees.[5] The angulation in the present study varied from 50 to 60 degrees. The course of anterior cerebral artery in relation with optic nerve, optic chiasma and optic tract is clinically important as pressure over this structures by arteries may produce various defects in visual fields.J.Peltier et al observed that the A1 segment of both sides anterior cerebral artery coursed inferior to the corresponding optic nerves.[6] In this study no such variations were noted.

SB Pai et al have reported that the length of A1 segment was in the range of 10mm to 19mm with a

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mean of 14.5mm on the left and 14.6mm on the right side. This segment was noted for hypoplastic changes.[5] In a past study by Slyvia Kamath the average length of A1 segment was 14.7mm on the right and 13.8mm on the left side.[7] In the present study the range coincides with the study of SB Pai et al.

S.B Pai et al reported that the outer diameter ranged from 2.5mm to 3.5mm with a mean of 2.9mm on the left and 2.8mm on the right side. As per his observation A1 hypoplasia was much more common when aneurysm was present. Local alterations of intra vascular dynamics might provide the mechanical basis for the development of these aneurysms.[5] Sylvia Kamath has stated that, the diameter of right anterior cerebral artery ranged from 1.6mm to 2.8mm, the average being 2.2mm. In the left anterior cerebral artery the range was from 1.9mm to 2.9mm with an average of 2.4mm.[7] As per the observation made by Keele & Neil the blood flow through shorter and wider vessels were more efficient since the volume of blood flow is inversely related to the length and directly related to the diameter. Hence blood flow will be better in the left half keeping with the dominance of left hemisphere and the common occurrence of right handedness.[8] According to Brust CM the diameter ranged from 0.9mm to 4mm with an average of 2.6mm and was more than 1.5mm in 90% of brains. In 74% the diameter was larger than the anterior communicating artery.[9] Perlmutter and Rhoton used 1.5mm as the cutoff figure for hypoplasia. They found 10% of the brains to have an A1 segment less than 1.5mm in diameter.[10] Alpers BJ,Berry RG & Paddison RM on their study found string like components in 28% of the A1segment.[11] Riggs & Rupp found A1 hypoplasia of 7% in one of the largest series studied.[12] Puchades-Orts et al reported on agenesis and hypoplasia of the initial segment of the anterior cerebral artery and anterior communicating arteries resulting in a defective circulation.[13] The present study revealed that the diameter was ranging from 1.5 to 3.5mm with a mean of 2.5mm on the right and 2.6mm on left side. Neither hypoplasia nor agenesis of the arteries was found out.

As per the standard description these A1 segment perforator arteries are divided into two groups, posteroinferior and posterosuperior. Posteroinferior perforators were generally very small twigs and about 2 to 3 in number per A1 segment situated more medially than laterally and supplied the optic nerve and optic chiasma. Posterosuperior perforators arose as a large stem divided into smaller branches and penetrated the anterior perforated substance. According to the site of origin A1 segment perforators were divided into proximal, middle and distal as demonstrated by SB Pai et al. On his study a mean of 3 perforators were found in the proximal portion, 1.7 in the middle portion and 1.6 in the distal segment. Barry reported the origin of perforators was unusual from the initial 5mm of A1. In the present study the perforators were in the range of 1 to 4 in number which mostly arises from the posteroinferior part of the A1 segment.

Distal anterior cerebral artery or A2 segment had been further classified into different segments by various authors. But in this study the part of the artery distal to the anterior communicating artery was considered as A2 segment, had diameter ranging from 2mm to 3.5mm with a mean of 2.5mm on both sides as described by SB Pai.

No major perforators were noted from the A2 segment as published by SB Pai. Perlmutter D & Rhoton AL noted an average of 4 perforating branches to the optic chiasma, lamina terminalis and anterior forebrain below the corpus callosum. The present study correlates to the report of SB Pai. The cortical branches seen constantly during the present study in all the fifty specimens were the orbitofrontal, frontopolar and callosomarginal arteries. The callosomarginal artery was seen to arise from the A2 segment at the genu of the corpus callosum after which the A2 segment continued as the pericallosal artery posteriorly. The A2 segments gave branches to both sides of the hemisphere in 4 cases with an incidence of 8% and were termed bihemispheric. In all this four cases the interhemispheric branches were given off from the right to the left side and so the diameter of the right A2 segment in these specimens were larger than the left side. All this data obtained in the present study correlates with the previous study done by SB Pai, Paul S & Mishra S. They described the anastomoses between the two anterior cerebral arteries with narrowing of one side so that the artery of the opposite side crossed over to compensate for the vascular insufficiency. Aneurysms of the A2 segment can occur all along the course of the artery but was seen commonest at the origin of the callosomarginal artery. Perlmutter D, Rhoton AL stated that unusual variants may cause aneurysms to develop at other sites by altering the flow dynamics. No such variation was noted in the present study.

S.B. Pai et al observed in one case that the anterior communicating artery gave rise to the pericallosal artery which coursed directly anterosuperiorly over the genu and then posteriorly over the corpus callosum. No such variations were noted in the present study.

Ferguson stated that the unusual anatomical variations of the cerebral vessels may cause a flow disturbance leading to aneurysm formation. This assumption was supported by Yasargil by finding two cases with aneurysm of the unpaired pericallosal artery.[14] Schick RM et al observed an azygos or unpaired anterior cerebral artery that unites the anterior cerebral artery to form a common link. It was one of the rare anomalies of the cerebral vessels with an incidence of 1.15% in human autopsy cas). No such variation was seen in the present study.

Nicole S Burbank & Pearse Morris quoted that an anomalous origin of the anterior cerebral artery from the contra lateral internal carotid artery was very rare and they differ in the course while ascending to its normal position. This infra optic course of the A1 segment was associated with agenesis or hypoplasia of the contralateral A1 with a higher prevalence of cerebral aneurysms and arteriovenous malformations.

Embryological Significance

Cerebro vascular ontogenic plasticity theory suggested that altered blood flow dynamics during embryogenesis may account for these coexistent anomalies. The recognition of these anomalies were crucial when planning surgical or endovascular treatment of aneurysms.

Radiological Significance

The circulus arteriosus offers a potential shunt in abnormal conditions such as occlusions and spasms. In normal circumstances it was not an equalizer and distributor of blood from different sources. There was normally no mixing of the opposing stream of blood which meets in the middle of the anterior communicating arteries at points where the pressure of the two are equal. Anomalies of the artery may play a role in the development of aneurysm by producing hemodynamic changes in blood flow and inducing strain on the weak point of the arteries. The physiological alternation in blood flow may have a prognostic significance in the surgery of aneurysms. In about one third cases, angiographic evidence of defective circulation has been observed. Therefore existence of an effective circulation can never be assumed on surgical procedures involving its feeders and so all surgical interventions of the anterior cerebral artery should be preceded by angiography.

Clinical Significance

Perforators unusually took origin from the initial 5mm of A1 segment. So placing a clip on the anterior cerebral artery immediately after its origin from the internal carotid artery was usually advised. Posteroinferior perforators to the optic chiasma were very thin and few and may be injured during the retraction causing visual field defects after surgery in this area. The anterior boarder of the A1segment is generally devoid of any perforators and dissection may be carried along this boarder in approaching the anterior communicating artery. The posterosuperior perforators are seen more frequently in the lateral A1 segment than the medial portion. Hence it seems logical that during surgery the temporary clip which is found essential should be placed as medially as possible to avoid perforator ischemia. The anatomy of the branches of the anterior cerebral artery near the anterior communicating artery complex was investigated to minimize neurovascular morbidity caused by surgical procedures performed in this region. The recurrent artery of Heubner, orbito frontal artery and fronto polar artery were identified as the branches of the anterior cerebral artery arising near the anterior communicating artery complex. The orbito frontal artery always arose from the A2 segment was consistently the smallest branch and coursed to the gyrus rectus, olfactory tract and olfactory bulb. The mean distance between the anterior communicating artery and the orbito frontal artery was 5.96mm. The frontopolar artery arose from the A2 segment and coursed to the medial sub frontal region. The mean distance between the anterior communicating artery and the fronto polar artery was 14.6mm. The recurrent artery of Heubner, orbitofrontal artery and the fronto polar artery were the three branches that arise from the anterior cerebral artery near the anterior communicating artery complex. These vessels had similar diameters but can be distinguished by the final destination. Distinguishing these vessels is important since the consequences of injury or occlusion of the fronto polar artery and orbito frontal artery are significantly less than that of the recurrent artery of Heubner.

CONCLUSION

With the advances in micro- neurosurgery and the ability to tackle diseases of the intracranial arteries more effectively, accurate knowledge of the intra cranial vascular anatomy is important. This study presents variation in the dimensions and the branching pattern of anterior cerebral artery by an attempt to establish a norm with an expectation that it will hopefully contribute to better interpretation of diagnostic studies for better management and treatment.

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