Neurology Asia 2005; 10 : 21 – 28

Microsurgical anatomy of the anterior cerebral artery – anterior communicating artery complex: An Indian study

SB Pai, *RN Kulkarni, RGVarma

*Departments of Neurosurgery and *Anatomy, MS Ramaiah Medical College, Bangalore, India.*

Abstract

Objective: The microsurgical anatomy of the anterior cerebral artery (ACA), anterior communicating artery (ACoA), distal anterior cerebral artery (DACA) and its branches is complex and is known for its frequent variations. The purpose of this study was to document the microsurgical anatomy of this region in Indian population. *Methods:* Ten anterior cerebral artery complexes from cadaveric brain specimens were microscopically dissected and studied using the operating microscope under 5x to 20x magnification. The outer diameters and length of the proximal segment of the ACA (A1), ACoA and DACA (A2), branches of A1, ACoA and A2 segment and their origin and the various anomalies were documented. *Results:* The mean outer diameter of the A1 was 2.8 mm on the right side and 2.9 mm of the left side. The mean length of the A1 was 14.6 mm on either side. The mean outer diameter and length of the ACoA was 2.1 mm and 2.45 mm respectively. The DACA rarely gave rise to perforators. The origin of the recurrent artery of Heubner was at the A2-ACoA junction and proximal portion of A2 in most cases.
Conclusions: The variations in our study were found to be more in the ACoA and DACA segments rather than the A1 segments. The microsurgical anatomical knowledge of the ACA - ACoA complex is essential for a cerebrovascular surgeon.

INTRODUCTION

Aneurysms arising from the anterior communicating artery (ACoA) are the commonest and also considered the most complex among the anterior circle of Willis aneurysms. These constitute 30.3% of all cerebral aneurysms.[1] This is because of the complex anatomy of the area concerned compounded by the fact that variations of the normal anatomy are very frequent. Disregarding the various perforators and small arterioles in this area may cause unacceptable morbidity and mortality in that postoperative period. The purpose of the study was to define and document the microsurgical anatomy of the area among Indians, which was found to be infrequent in the literature.

METHODS

Ten anterior cerebral artery (ACA) complexes derived from cadaveric brain specimens were studied. Microscopic dissection was carried out from the internal carotid artery bifurcation, proximal ACA i.e. A1 segment, anterior communicating artery (ACoA) and distal anterior cerebral artery (DACA). Microscopic dissection was done using the Serwell operating microscope under 5x to 20x magnification. Particular attention was paid to the perforators in this area and the recurrent arteries. The DACA was dissected up to the formation of the pericallosal arteries. Measurements of the outer diameters of the A1, ACoA and the DACA were taken. Lengths of the A1 and ACoA were noted. In the case of the ACoA the average of the anterior and posterior lengths was taken. The divisions of the DACA up to the pericallosal arteries were studied. The cortical branches were not dissected as it was beyond the purview of the study. As the cadaveric specimens were not injected with intra-arterial dye meticulous dissection was done to distinguish the small perforators from arachnoid strands. The arterial system was then painted with watercolor and photographic documentation done using a digital camera.

RESULTS

The internal carotid artery bifurcates into the ACA and the middle cerebral artery. The ACA courses anteromedially to cross over the optic

Address correspondence to: Dr S. Balaji Pai, 737, 14th cross, Girinagar II Phase, Bangalore 560085, India. Tel: 91 080 26720003,
E mail : balajipai65@yahoo.co.in

nerve and optic chiasma to communicate with the opposite ACA through the ACoA. This segment, from origin to the anterior communicating artery, is referred to as the A1 segment.

The anterior cerebral artery A1 segment

The outer diameter of the internal carotid artery on both sides ranged from 3.5 mm to 5 mm with a mean of 4.35 mm on the left side and 4.2 mm on the right side. The ACA outer diameter on both sides ranged from 2.5 mm to 3.5 mm with a mean of 2.9 mm on the left side and 2.8 mm on the right side. On its course towards the ACoA the ACA took an anteromedial course at an angulation of 45^0 to 60^0 to the anteroposterior plane. In 2 cases it was 80^0. The diameter of the ACA was larger on the left side in 4 cases and on the right side in 2 cases. In the remaining 4 cases the ACAs were of equal diameters on both sides but in no situation was the difference larger than 1mm. The length of the ACA ranged from 10 mm to 19 mm with a mean of 14.5 mm on the left side and 14.6 mm on the right side.

Anterior cerebral artery A1 segment perforators

The perforator arteries are divided into two groups, posterior inferior and posterior superior.

a) Posteroinferior

These perforators arise from the posteroinferior surface of the A1 segment of the ACA and supplied the optic nerve, optic chiasma and sometimes the optic tract. These were generally very small twigs and few in number (2 to 3 in number) per A1 segment. These were situated more medially than laterally.

b) Posterosuperior

These perforators arose from the posterosuperior surface of the A1 segment and coursed upwards directly and penetrated the anterior perforated substance (Fig. 1). These perforators either arose as a large stem artery, which divided into smaller branches or arose directly as small branches. The A1 segment perforators were divided according to their site of origin – proximal, middle and distal A1 segment perforators. In our study a mean of 3 perforators were found in the proximal portion of A1, 1.7 in the middle portion and 1.6 in the distal segment. The lateral perforators pierced the anterior perforated substance in its lateral portion while the medial perforators entered the medial anterior perforated substance. These perforators supply the optic chiasma, the anterior commisure, the anterior hypothalamus, the genu of the internal capsule and the anterior part of the globus pallidus and at times may extend to the posterior limits of the internal capsule and anterior part of the thalamus. This area is below the anteromedial part of the territory supplied by the lenticulostriate arteries.

Anterior communicating Artery

The ACoA was found in all the cases in our study. The ACoA was situated above the optic chiasma. The diameter of the ACoA (anteroposterior) ranged from 1 mm to 3.5 mm with a mean of 2.1 mm. The length of the ACoA ranged from 1 mm to 4 mm with a mean of 2.45 mm. The diameter (width) of the ACoA was less than the length in 5 cases, equal to the length in one case and more than the length in the remaining 3 cases. The ACoA was horizontally placed in 9 cases but was obliquely disposed in one specimen (Fig. 2). There was a trabeculation in one case and a fenestration in another case (Fig. 3). In two cases there was duplication of the ACoA including one, which was thin and rudimentary (Fig. 4). The other and better-formed duplication of the ACoA gave origin to a perforator.

Anterior communicating artery perforators

All the ACoAs in our study gave rise to perforators. These ranged from one to 5 in number with a mean of 3. These arose from the posterosuperior surface of the ACoA and coursed superiorly (Fig. 5). They arose as a large stem vessel or thin small vessels. In one case the ACoA gave rise to the pericallosal artery which coursed directly anterosuperiorly over the genu and then posteriorly over the corpus callosum.

The recurrent artery of Heubner

This artery doubles back and runs parallel and anterior to the A1 and pierces the anterior perforated substance at the lateral portion (Fig. 6). It was seen to arise from the A2 - ACoA junction in 11 cases, from the proximal portion of the DACA in 3 cases, A1 - ACoA junction in one case, A1 segment in 2 cases and as a common origin with the medial orbitofrontal branch in 2 cases. The recurrent artery of Heubner was absent on one side in one brain. The uncal artery in this case was large and arose from the A1 segment very close to its origin and gave a branch which pierced the anterior perforated substance in its

Figure 1: A1 segment of the anterior cerebral artery demonstrating the perforators

RICA-Right internal carotid artery
RMCA- Right middle cerebral artery
RA1- Right proximal anterior cerebral artery

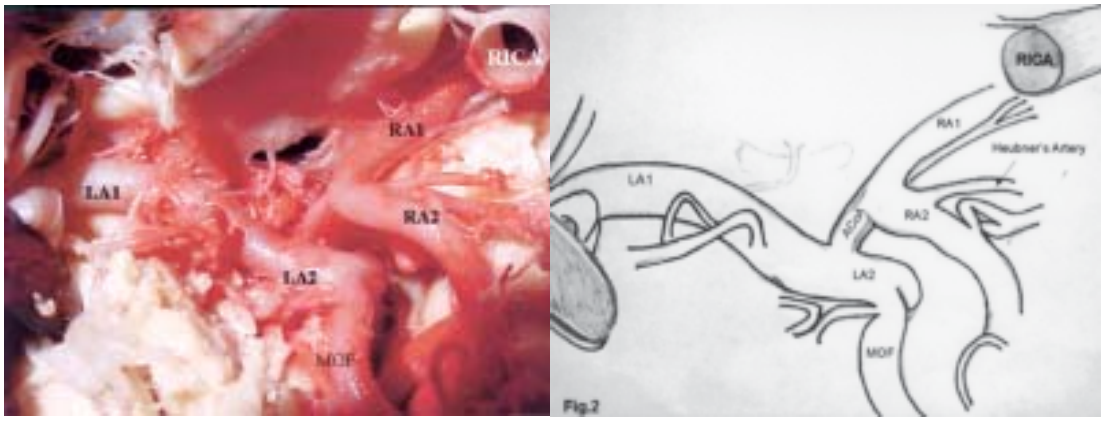

Figure 2: Obliquely disposed anterior communicating artery with bilateral A1 and A2 segments

RICA-Right internal carotid artery
LA1- Left proximal anterior cerebral artery
RA1- Right proximal anterior cerebral artery
LA2- Left distal anterior cerebral artery
RA2- Right distal anterior cerebral artery
ACoA- Anterior communicating artery
MOF- Medial orbitofrontal artery

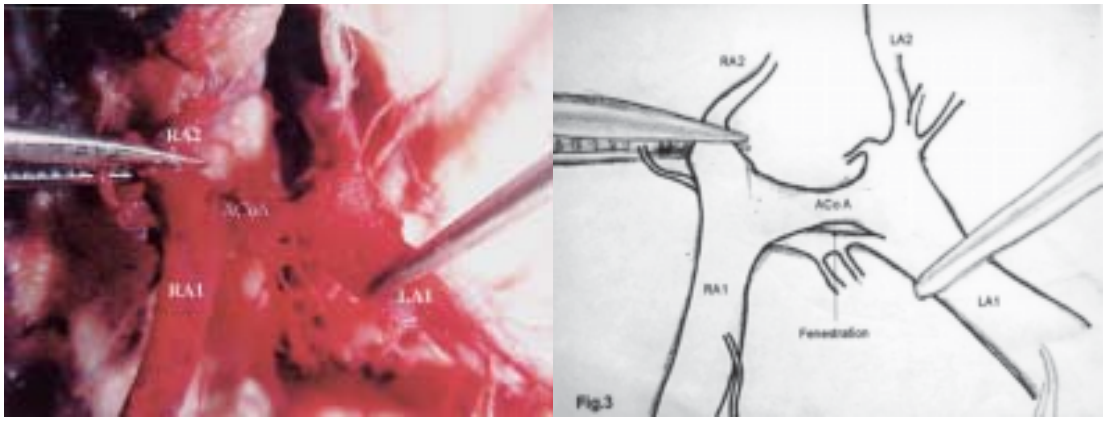

Figure 3: Fenestration in the anterior communicating artery

LA1- Left proximal anterior cerebral artery
RA1- Right proximal anterior cerebral artery
LA2- Left distal anterior cerebral artery
RA2- Right distal anterior cerebral artery
ACoA- Anterior communicating artery

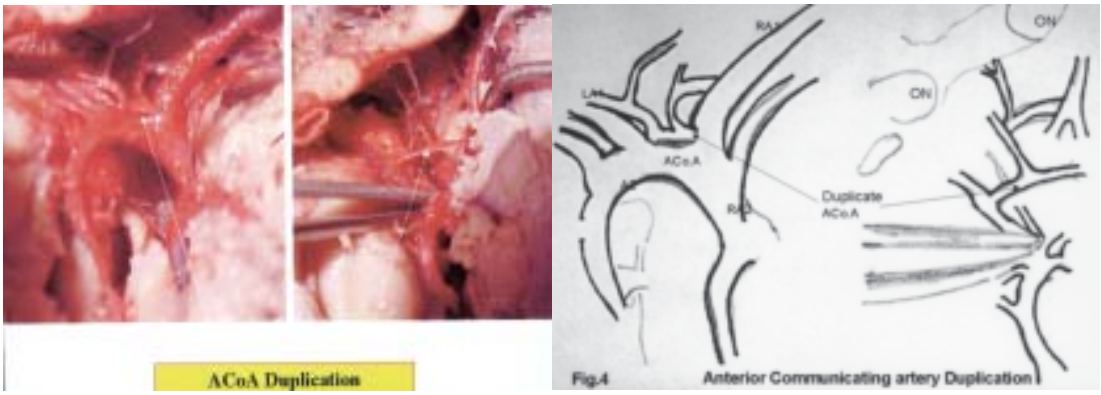

Figure 4: Two cases of anterior communicating artery duplication

LA1- Left proximal anterior cerebral artery
RA1- Right proximal anterior cerebral artery
LA2- Left distal anterior cerebral artery
RA2- Right distal anterior cerebral artery
ACoA- Anterior communicating artery
ON- Optic Nerve

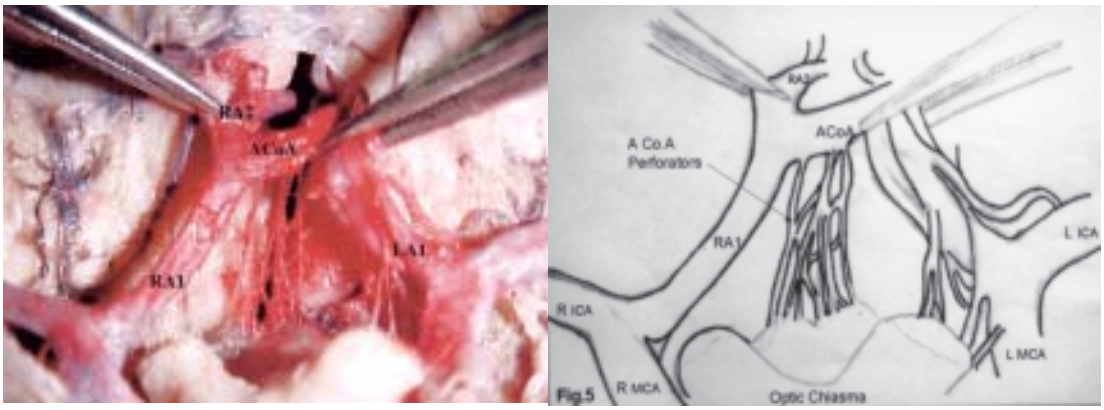

Figure 5: Anterior communicating artery perforators demonstrated coursing superiorly and posteriorly

RICA-Right internal carotid artery
RMCA- Right middle cerebral artery
LICA- Left internal carotid artery
LMCA- Left middle cerebral artery
RA1- Right proximal anterior cerebral artery
RA2- Right distal anterior cerebral artery
ACoA- Anterior communicating artery

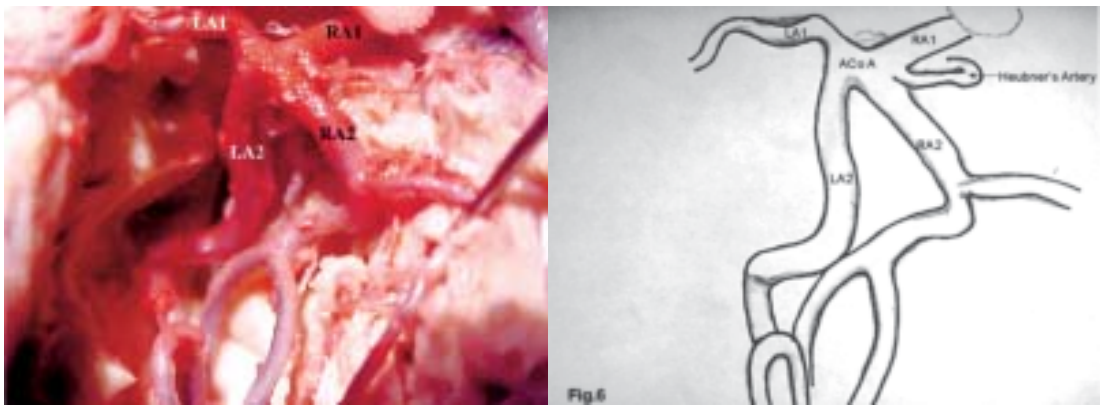

Figure 6: The recurrent artery of Heubner originating at the anterior communicating artery - A2 junction

LA1- Left proximal anterior cerebral artery
RA1- Right proximal anterior cerebral artery
LA2- Left distal anterior cerebral artery
RA2- Right distal anterior cerebral artery
ACoA- Anterior communicating artery

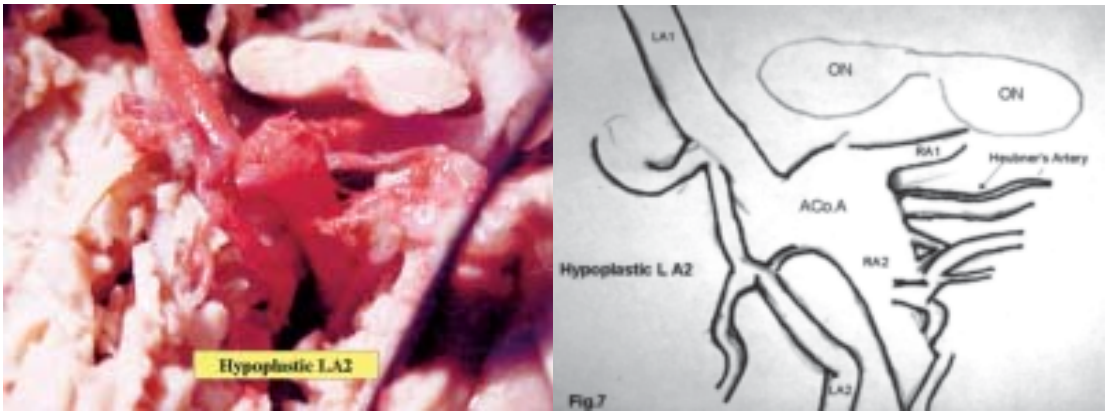

Figure 7: Specimen showing a left hypoplastic A2 while the right A2 seems to compensate

LA1- Left proximal anterior cerebral artery
RA1- Right proximal anterior cerebral artery
LA2- Left distal anterior cerebral artery
RA2- Right distal anterior cerebral artery
ACoA- Anterior communicating artery
ON- Optic Nerve

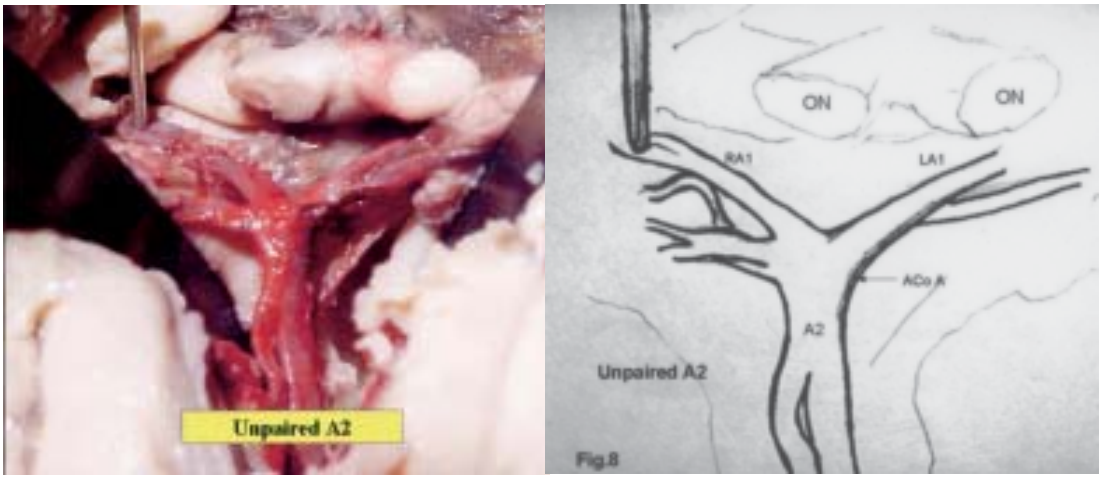

Figure 8: Unpaired A2 segment

LA1- Left proximal anterior cerebral artery
RA1- Right proximal anterior cerebral artery
ACoA- Anterior communicating artery
ON- Optic Nerve

lateral portion in the same area that the recurrent artery of Heubner was expected to pierce the anterior perforated substance. Apart from the recurrent artery of Heubner, another smaller recurrent artery was seen in 7 cases, 5 proximal to the recurrent artery of Heubner and 2 distal to the recurrent artery of Heubner.

Distal anterior cerebral artery

The portion of the ACA complex distal to the ACoA is referred to as the DACA or A2 in our study. The A2 diameter ranged from 1.5 mm to 4 mm with a mean of 2.5 mm on the left side and 2.6 mm on the right side. In 5 cases both the A2 segments were of equal diameter, right A2 larger in 3 cases and the left larger in 2 cases. A2 segment was hypoplastic in 3 cases – 2 on the left and one on the right (Fig.7). In one case an unpaired A2 segment was seen originating from the ACoA, which later divided into further branches after a distance of 9 mm (Fig. 8). The A2 segments hardly gave rise to any perforators apart from the recurrent arteries. However they did give rise to small twig like branches to the adjacent cortex. The cortical branches that were seen constantly were the medial orbitofrontal, frontopolar and callosomarginal arteries. The DACA continued as the pericallosal artery. The callosomarginal artery was seen to arise from the A2 segment at the genu of the corpus callosum after which the pericallosal artery would turn

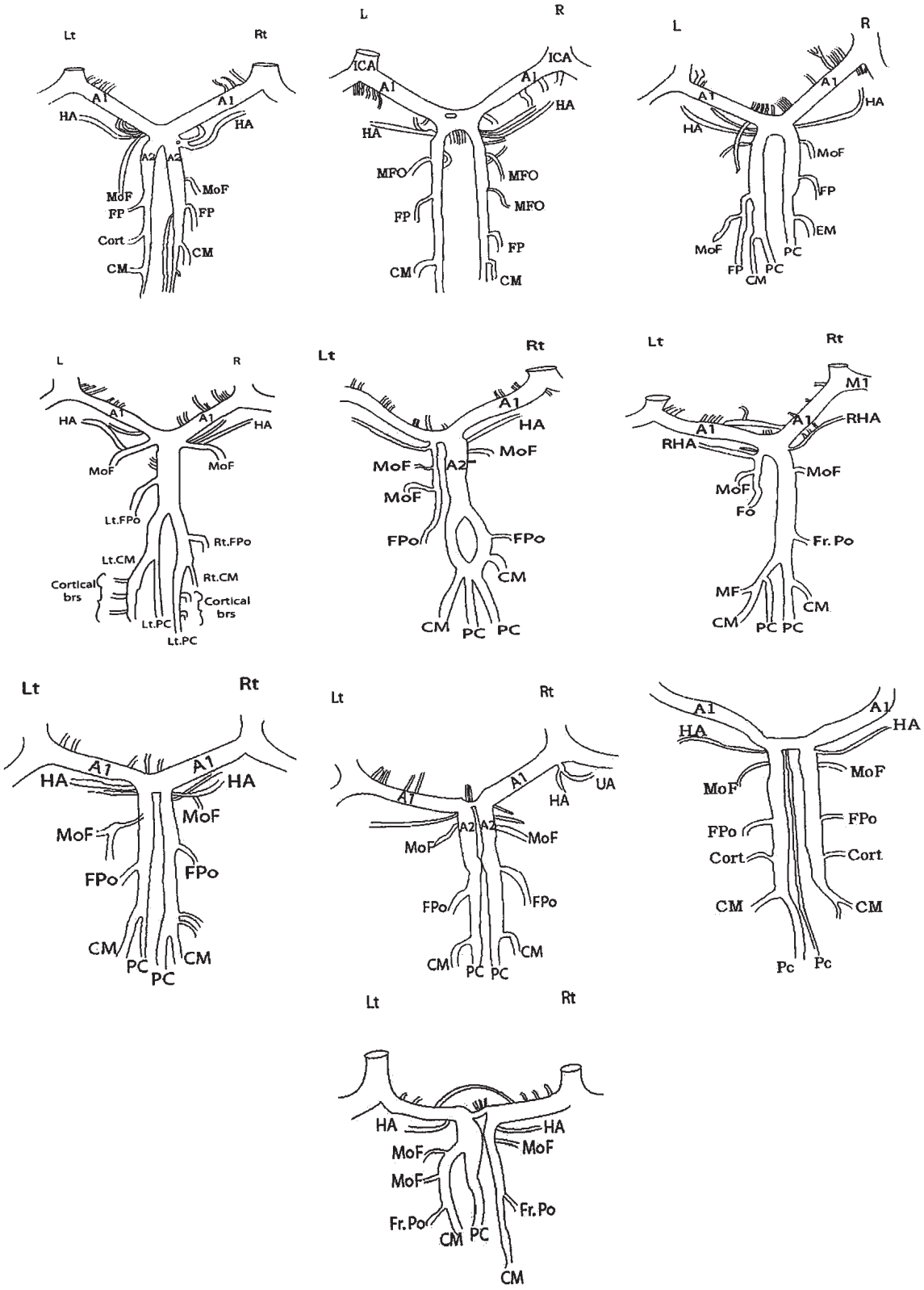

Figure 9: Schematic diagram of all the dissected specimens: A1 - proximal anterior cerebral artery, HA - recurrent artery of Heubner; MoF, MFO - medial orbitofrontal artery; FP, FPo - frontopolar artery, CM - callosomarginal artery, PC - pericallosal artery

posteriorly. The A2 segments gave branches to both sides of the hemisphere in 8 cases (5 right A2 and 3 left A2) and were termed bihemispheric. Unihemispheric A2 segments were seen in 12 cases – 7 left A2 and 5 right A2. The pericallosal artery was larger than the callosomarginal artery in 11 cases while the reverse was seen in 6 cases and both were equal in 3 cases. In one case a single pericallosal artery was found supplying both sides. The size of the callosomarginal artery and pericallosal artery was proportional to the cortical branches supplied by them. Detailed dissection of the cortical branches was not done.

DISCUSSIONS

The ACA - ACoA complex is well known for its anatomical variants. Much has been discussed in literature about the size of the A1 segment of the ACA. The diameter below which the A1 segment could be called hypoplastic has not been well defined, but Perlmutter and Rhoton used 1.5 mm as the cut off figure.[2] They found 10% of the brains to have an A1 segment less than 1.5 mm in diameter. Alpers *et al* found string like components of one of the vessels of the circle of Willis in 28%, with the A1 being the predominant site. Riggs and Rupp found A1 hypoplasia in 7% of one of the largest series studied.[2,3] In our series no A1 hypoplasia was noted, probably due to the small sample size. Our measurements of the ACA was comparable with those of Yasargil.[3] It appeared that A1 hypoplasia was much more common when ACoA aneurysm was present.[2] Wilson *et al* reported an incidence of 85% in 40 ACoA aneurysms.[3] Kwak and Suzuki reported an incidence of 68.1% in a similar study.[3] Local alterations of intravascular dynamics might provide the mechanical basis for the development of these aneurysms.[2]

Posteroinferior perforators to the optic chiasma are very thin and few, and may be injured during the retraction causing visual field defects after surgery in this area. The anterior border of the A1 segment is generally devoid of any perforators and dissection may be carried along this border in approaching the ACoA. The posterosuperior perforators are seen more frequently in the lateral A1 segment than the medial portion in various studies as well as in our studies.[2,3] Hence it seems logical that during surgery the temporary clip, which if found essential, should be placed as medially as possible to avoid perforator ischemia. Also care should be taken to avoid the recurrent artery of Heubner. This however contrasts with Barry's report that found it unusual for any perforator to originate from the initial 5 mm of A1. He advocated placing a clip on the ACA immediately after its origin from internal cerebral carotid artery.[2] The A1 perforators supply the area around the optic chiasma, the anterior commisure, the anterior hypothalamus, the genu of the internal capsule and the anterior part of the globus pallidus.[2,4]

The ACoA was seen situated above the optic chiasma. It was situated in the transverse plane but occasionally it was obliquely placed. Perlmutter and Rhoton observed that there was a direct correlation between the difference in size between the A1 segments and the diameter of the ACoA – the greater the difference, the larger the size (diameter) of the ACoA.[2] This correlation however was not observed in our study. The dimensions of the ACoA in our series was consistent with that by Yasargil.[3] Hypoplasia or aplasia of the ACoA was not seen but very short ACoA (1.5mm) was seen in 2 of our cases. Various kinds of duplication, triplication, fenestrations, trabeculations, reticular patterns, loops, and bridges were noted by Yasargil in his series.[3] In our small series, duplication, fenestration and trabeculations were also noted.

Some authors (Critchley 1930, Grinker 1934) emphatically stated that the ACoA had no branches.[3] Senior (1923), Lewis (1936) and Rubenstein (1944) demonstrated the presence of perforators in the ACoA.[3] Yasargil demonstrated the same since 1969 and was followed by many authors – Krayenbuhl & Yasargil 1972: Yasargil et al 1975; Densker and Harris 1976; Perlmutter and Rhoton 1976; Crowell and Morawetz 1977; Lang 1979.[3] Perforating branches were seen in all the cases in our series. These branches were traced to the region of the infundibulum and hypothalamus where they penetrated the brain substance to supply the preoptic area of the hypothalamus.[3] Perlmutter and Rhoton reported that they arose from the posterior and superior surface in 90% of the cases.[2] This was also observed in our series. Occlusion of these perforators with the aneurysm clip is a major cause of morbidity and mortality in patients with ACoA aneurysms pointing posteriorly or superiorly. It was noted in our dissections that a clear view of the ACoA was usually hindered by the overhanging gyrus rectus. The same required to be excised to obtain optimum visualization and space for surgical manipulation in this area.

Heubner first described the recurrent artery of Heubner in 1874. This was fairly constantly seen

in our series and originated from the A2-ACoA junction or distal to it in 80% of the cases. Perlmutter and Rhoton found the origin of the recurrent artery of Heubner at the A2 segment in 78%, A1 in 14% and at ACoA in 8%.[2] The size varies and it is usually seen anterior to the A1 or superior to it.[1] It is the first artery seen on retracting the frontal lobe. It may get injured while applying the temporary clip or while excising the small portion of the gyrus rectus. This may give rise to hemiparesis with brachial predominance. This is because it supplies the anterior limb of the internal capsule, anterior part of the caudate nucleus, anterior third of the putamen, tip of the outer segment of the globus pallidus. Aphasia may also occur with occlusion of the dominant recurrent artery of Heubner.

The DACA has been further classified into different segments by various authors.[5] Fischer subdivided the DACA into 4 segments.[5] The A2 segment began at the ACoA and ended at the junction of the rostrum and genu of the corpus callosum. The A3 segment extended from the genu of the corpus callosum and ended where the artery turned sharply posterior above the genu. A4 and A5 segments were located on the corpus callosum and were divided into anterior (A4) and posterior (A5) portions by an imaginary line just posterior to the coronal suture. Our study has been restricted to the A2 and A3 segments. The space between the two A2 segments is very much less, and in some cases they may be intertwined when compared to the larger space available between the two A1 segments. This predisposes these segments for occlusion by the aneurysm clip in posteriorly or superiorly directed ACoA aneurysms.

No major perforators were noted in our study from the A2 segments. This is in contrast to Perlmutter and Rhoton, who noted an average of 4.8 perforating branches to the optic chiasma, lamina terminalis and anterior forebrain below the corpus callosum.[2]

The medial orbitofrontal artery and the frontopolar artery were seen in all cases. Callosomarginal artery too was found constantly and seen to usually arise at the genu of the corpus callosum. Other cortical branches named are the internal frontal arteries, paracentral artery and parietal arteries.[5] Aneurysms of the DACA can occur all along the course of the artery but is seen commonest at the origin of the callosomarginal artery. Unusual variants may cause aneurysms to develop at other sites by altering the flow dynamics.[5]

In conclusion, the anatomy of the ACA - ACoA complex is very varied and consequently the surgery in this area is extremely challenging. The variations in our study among Indians were found to be more in the ACoA and DACA segments rather than the A1 segments. The majority of the aneurysms in this area point anteriorly and inferiorly and are safely clippable.[2] The posterior and superiorly pointing aneurysms are fraught with more risks due to the proximity and involvement of ACoA perforators, recurrent artery of Heubner and A2 segments.

REFERENCES

1. Weir B, Macdonald LR. Aneurysms and subarachnoid hemorrhage. In: Wilkins RH, Rengachari S, eds: Neurosurgery. 2nd edition. New York: Mc Graw Hill, 1996: 2191-213.
2. Perlmutter D, Rhoton AL. Microsurgical anatomy of the anterior cerebral artery- anterior communicating artery- recurrent artery complex. *J Neurosurg* 1976; 45: 259-72.
3. Yasargil MG. Intracranial arteries. In: Yasargil MG. Microneurosurgery. Vol I. New York: Thieme Medical Publishers Inc., 1987: 54-164.
4. Rosner SS, Rhoton AL, Ono M, Barry M. Microsurgical anatomy of the anterior perforating arteries. *J Neurosurg* 1984; 61: 465-8.
5. Perlmutter D, Rhoton AL. Microsurgical anatomy of the distal anterior cerebral artery. *J Neurosurg* 1978; 49: 204-28.
6. Dunker RO, Harris AB. Surgical anatomy of the proximal anterior cerebral artery. *J Neurosurg* 1976; 44: 359-67.
7. Ostrowski AZ, Webster JE, Gurdjian ES. The proximal anterior cerebral artery: an anatomic study. *Arch Neurol* 1960; 3: 661-4.