Surgical strategy for distal anterior cerebral artery aneurysms: microsurgical anatomy

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Object. Most distal anterior cerebral artery (ACA) aneurysms arise at the pericallosal–callosomarginal artery (PerA–CMA) junction, which is usually located in the A3 segment of the ACA around the genu of the corpus callosum. Aneurysms in the PerA–CMA junction are divided into two types according to their location: supracallosal and infracallosal. Infracallosal distal ACA aneurysms are defined as those located in the lower half of the A3 segment, which makes it more difficult to gain proximal control. In this study, the authors examined the microsurgical anatomy of the distal ACA region, focusing especially on the relationship between the PerA and CMA located in the lower half of the A3 (infracallosal) segment, and present a surgical strategy for dealing with distal ACA aneurysms.

Methods. The microsurgical anatomy of the distal ACA region was examined in 22 adult cadaveric cerebral hemispheres after perfusion of the arteries and veins with colored silicone. The relationships of the infracallosal segment of the PerA to the CMA and the A3 segment of the PerA to the frontopolar artery were examined. The distance between the nasion and the site at which a parallel line directed along the long axis of the infracallosal PerA just proximal to the origin of the CMA artery crosses the forehead (which we have named the PC point) was also measured. Surgical approaches to distal ACA aneurysms were examined in stepwise dissections.

Conclusions. The PerA–CMA junctions were located in the supracallosal and infracallosal segments of A3 in 36 and 55% of cases, respectively. In the infracallosal region, it was difficult to identify the proximal PerA and to establish proximal control of the vessel. The infracallosal part of the proximal PerA coursed almost parallel to the frontal cranial base, and the PC point was 42.2 ± 15.9 mm (mean ± standard deviation) from the nasion. These findings indicate that there is only a limited space in which to access an infracallosal distal ACA aneurysm below the PC point and establish proximal control by the anterior interhemispheric approach. When the approach is made above the PC point, an anterior callosotomy may be necessary to establish proximal control before final aneurysm dissection and clip placement are completed. The PC point is an important surgical landmark in planning the surgical strategy for infracallosal distal ACA aneurysms.

Key Words • aneurysm • anterior cerebral artery • pericallosal artery • callosomarginal artery • pericallosal point • anterior interhemispheric approach

The distal segment of the ACA, or PerA, is defined as the portion distal to the ACoA.14 Aneurysms on the distal ACA and its branches are uncommon, comprising approximately 5% of all intracranial aneurysms. Most arise at the bifurcation formed by the origin of the CMA from the PerA.3,10,11,15,18 Unique problems presented by these aneurysms that require surgical approaches that differ from those directed to other aneurysms on the anterior part of the circle of Willis include the narrow surgical corridor between the skull base and corpus callosum, the difficulty establishing proximal control, and the projection of the aneurysm dome toward the surgeon.8,21 In this study, we present the microsurgical anatomy of the distal ACA region, focusing especially on the relationship between the PerA and CMA located in the lower half of the A3 segment, and demonstrate the surgical strategy for reaching a distal ACA aneurysm.

Clinical Material and Methods

Cadaveric Specimens

The microsurgical anatomy of the distal ACA region was examined in 22 adult cadaveric cerebral hemispheres by using 3× to 40× magnification after perfusion of the arteries and veins with colored silicone. The sites of the PerA–CMA junction were divided into supracallosal and infracallosal groups based on their relationship to the midportion of the genu of the corpus callosum in the lateral view.

Classification of the Distal ACA

In this study, the distal ACA was divided into four segments (A3–A5) as previously described (Fig. 1A).14 Segment A5 is the proximal segment between the internal carotid artery and the ACoA. Segment A5 begins at the ACoA, passes anterior to the lamina terminalis, and terminates in the subcallosal area at the junction of the rostrum and the genu of the corpus callosum. Segment A5 extends around the genu of the corpus callosum and terminates where the artery turns...
sharply posterior above the genu. Segments A4 and A5 are located above the corpus callosum and are separated into an anterior (A4) and posterior (A5) portion by a point bisected in the lateral view close behind the coronal suture.

Procedures Used for Measurements

Measurements obtained in this study, as shown in Fig. 1, were divided into two groups. In the first group, the relationship between the PerA and CMA, if they were located in the lower half of the A3 (infracallosal) segment, was examined by measuring the angles between lines directed along the long axis of the PerA just distal (angle a) and proximal (angle b) to the origin of the CMA and the long axis of the initial segment of the CMA; (b) angle between lines directed along the long axis of the PerA just proximal to the origin of the CMA and the long axis of the initial segment of the CMA; (c) angle between the proximal PerA (A2) and the initial segment of the FPA (Front. Pol. A.); (d) angle between lines directed along the long axis of the PerA just proximal to the origin of the CMA (infracallosal A3) and the long axis of the frontal cranial base; (e) angle between the lines directed along the long axis of the PerA just proximal to the origin of the FPA and the long axis of the frontal cranial base; (f) distance between the nasion and the site (PC point) at which a line directed along the infracallosal part of the PerA crosses the forehead; (g) anteroposterior thickness of the genu of the corpus callosum.

Surgical Approaches to Distal ACA Aneurysms

The anterior interhemispheric approach to distal ACA aneurysms, including supracallosal and infracallosal PerA–CMA aneurysms in A3, and PerA–FPA aneurysms in A2, were examined in stepwise dissections.
A CoA (A Co.A.) in front of the lamina terminalis to enter the interhemispheric fissure (A 1 ). Above the lamina terminalis, the artery makes a smooth curve around the genu of the corpus callosum (A 2 ) and then courses backward above the corpus callosum in the pericallosal cistern (A 3 and A 4 ). The PerA often has three convex curves as viewed laterally: the convexity is anteroventral at the junction of the A 1 and A 2 as it enters the interhemispheric fissure in the A 2 segment; posterosuperior at the junction of the A 2 and A 3; and anterior as it courses around the genu of the corpus callosum. The CMA is defined as the artery that courses in or near the cingulate sulcus and gives rise to two or more major cortical branches. E: Anterior view in which the veins of the frontal lobe are divided into groups that drain the lateral, medial, and basal surfaces of the lobe. The ascending veins of the lateral group are the frontopolar; anterior, middle, and posterior frontal; precentral; and central veins. The frontopolar vein enters the superolateral edge of the SSS. The anterior frontal vein drains the area adjoining that drained by the frontopolar vein and is directed forward and slightly upward to reach the area behind the frontal pole. The middle frontal vein pursues an anterosuperior course, and the posterior frontal vein follows a superior course. The ascending veins of the medial group are the anteromedial, centromedial, and postero medial frontal and paracentral veins. They drain the majority of the medial surface of the superior frontal gyrus and the adjoining part of the cingulate gyrus. The anterior group of the basal surface is composed of the anterior frontoorbital and frontopolar veins. A. = artery; A.I.F.A = anterior internal frontal artery; Ant. = anterior; Calc. = calcareine; Cent. = central; Cing. = cingulate; CN = cranial nerve; Front. = frontal; Front. Pol. = frontopolar; Gy. = gyrus; Lat. = lateral; Lob. = lobe; M.C.A. = middle cerebral artery; Med. = medial; Mid. = middle; M.I.F.A. = middle internal frontal artery; Occip. = occipital; Of. = orbitofrontal; Olf. = olfactory; Orb. = orbital; Par. = parietal or parieto-; Paracent. = paracentral; PC–CM = PerA–CMA; P.I.F.A. = posterior internal frontal artery; Post. = posterior; Sag. = sagittal; Sub. = subfrontal; Sub. Par. = subparietal; Sulc. or Sul. = sulcus; Sup. = superior; Temp. = temporal; V. = vein; Vent. = ventricle.
spheres, followed by the CMA (9%) and the A2 segment. The PerA usually courses along the genu of the corpus callosum in the pericallosal cistern (A3) and (A4). The PerA–CMA junctions were located in the infracallosal portion of the distal ACA. The mean angles of the proximal and distal PerA to the CMA were 63.1 ± 33.1° (angle a) and 131.9 ± 20.4° (angle b), respectively. The mean angle of the proximal PerA to the frontal cranial base was 23.2 ± 18.1° (angle d). The mean distance between the nasion and the PC point was 42.2 ± 15.9 mm (f).

The PerA and FPA in the A2 Segment of the Distal ACA. In 19 (86%) of 22 hemispheres, the PerA–FPA junctions were located in the A2 segment of the distal ACA. The mean angles of the proximal PerA to the FPA and the frontal cranial base were 77.7 ± 19.1° (angle c) and 66.1 ± 23.3° (angle e), respectively.

Genu of the Corpus Callosum. The mean anteroposterior distance of the genu of the corpus callosum in all specimens examined was 11.2 ± 2 mm (g).

Surgical Approaches to Distal ACA Aneurysms

Supracallosal distal ACA aneurysms are defined as those located on the upper half of the A2 segment, whereas infracallosal distal ACA aneurysms are those located on the lower half of the A2 segment. Most arise at the PerA–CMA junction. Both lesions can be approached through the interhemispheric route (Fig. 3). Another dominant site for distal ACA aneurysms is the PerA–FPA junction. The lesion can be accessed either via the pterional or anterior interhemispheric approach, depending on its location.

Supracallosal Distal ACA Aneurysms. Supracallosal distal ACA aneurysms can be treated via the anterior interhemispheric approach. This approach is directed along the nondominant right side through a unilateral frontal craniotomy. An attempt is made to enter the interhemisphere where there are no bridging veins to the SSS. The genu of the corpus callosum is exposed superior to the PerA–CMA aneurysm, and the aneurysm complex, which consists of the proximal and distal arteries and the lesion’s neck, can be observed (Fig. 4A–C).

Infracallosal Distal ACA Aneurysms.

1) Anterior Interhemispheric Approach Above the PC Point. This approach allows us to access the infracallosal PerA–CMA aneurysms above the PC point with or without an incision in the genu of the corpus callosum. This approach is directed along the nondominant right side through a unilateral frontal craniotomy that includes the PC point in the middle of the craniotomy. An attempt is made to enter the interhemisphere where there are no bridging veins to the SSS. The genu of the corpus callosum is exposed superior to the PerA–CMA aneurysm (Fig. 4A–C). An anterior callosotomy may be performed if needed to gain proximal control of the PerA. The aneurysm complex, which consists of the proximal and distal arteries and the aneurysm neck, is clearly observed from above to the genu of the corpus callosum (Fig. 4D and E).
2) Anterior Interhemispheric Approach Below the PC Point. This approach allows us to access the infracallosal PerA–CMA aneurysms below the PC point to establish proximal control of the PerA. The lesion should be approached from the nondominant right side through a unilateral frontal craniotomy anterior to the coronal suture, including the PC point in the upper part of the craniotomy and extending the frontal cranial base (Fig. 5A and B). When the distance between the nasion and PC point is short, the craniotomy is further extended into the anteromedial part of the frontal base and nasal bone (Fig. 5C and D). The dura is opened to the midline, with care taken not to damage the bridging veins. It may be necessary, however, to sacrifice a bridging vein passing toward the SSS before retracting the frontal lobe. After attempting to spare the olfactory nerve, the interhemispheric fissure is opened by proceeding along the lower edge of the ipsilateral side of the falk. Approaching the aneurysm more superiorly risks rupture because the aneurysm apex projects anterosuperiorly. After defining the ACoA and A2, the distal ACA is followed distally to imme...
diately proximal to the aneurysm in preparation for temporary occlusion, if needed.

A PerA–FPA Aneurysm in A2. The lesion should be approached along the anteroinferior border of the interhemispheric fissure just above the frontal cranial base. After defining the ACoA and A2, the proximal artery and neck of the aneurysm are exposed for clip occlusion (Fig. 5E and F). If an aneurysm is located on the lower part of A2 near the ACoA, the pterional or subfrontal approach may be used.

Discussion

Distal ACA aneurysms present special problems, including the narrow working space in the interhemispheric fissure and the callosal cistern; dense adhesions between the cingulate gyri; a broad-based and/or a sclerotic aneurysm neck; difficulty in identifying the parent artery; the fixed dome on the pial layer; and the association of an azygos ACA with the presence of multiple aneurysms.23,24 An
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Fig. 5. Photographs of cadaveric brains showing the anterior interhemispheric approach below the PC point to infracallosal PerA–CMA and PerA–FPA aneurysms, anterior view. A–D: Approaches to the infracallosal PerA–CMA aneurysms. A and B: This approach below the PC point exposes the infracallosal area where infracallosal PerA–CMA aneurysms arise and provides proximal control of the PerA. C and D: When the distance between the nasion and PC point is short, as seen on angiography, the craniotomy is extended downward into the anteromedial part of the frontal base and the nasal bone. After attempting to spare the olfactory nerve, the interhemispheric fissure is opened by proceeding along the side of the ipsilateral falx at its junction with the cranial base to prevent premature rupture. After defining the ACoA and A2, the distal ACA is followed distally to immediately proximal to the aneurysm in preparation for temporary occlusion, if needed. E and F: Approach to the infracallosal PerA–FPA aneurysms. The lesion can be approached as low as possible along the frontal cranial base. After identifying the ACoA and A2, the proximal artery and neck of the aneurysm are observed in the operative field. Then, clip occlusion of the neck of the aneurysm can be achieved. Fiss. = fissure; Inter- hemi. = interhemispheric.
anomaly often associated with distal ACA aneurysms is an azygos vessel, in which the ACA distal to A1 is unpaired and a single distal ACA supplies both hemispheres. An azygos ACA has been reported in 0.26 to 2.6% of autopsy cases,1,20 and in 0.2 to 3.7% of angiographically studied cases.6,8,10, however, a high incidence of azygos ACAs, ranging from 7.1 to 15.8%, has been reported in patients with distal ACA aneurysms.11,12,11 A high incidence of multiple aneurysms, ranging from 18.2 to 55%, has also been noted in patients with distal ACA aneurysms.10,12,17,18,22–24,26

Another problem associated with these aneurysms is that they are prone to rupture during exposure; intraoperative rupture has been reported in up to 50% of these lesions.3,6,8,10,11,15,18,22 The reasons for the propensity to intraoperative rupture are that the dome of the aneurysm projects toward the surgeon and is exposed before the neck is seen. The aneurysm is often embedded in the frontal lobe, where aggressive manipulation or retraction may avulse the underlying lesion. The intraoperative mortality rate has ranged from 0 to 15%, with morbidity reported at approximately 20%.6,8,10,12,24

Distal ACA aneurysms are most treated via an interhemispheric approach. Nevertheless, the pterional and subfrontal approaches with initial proximal exposure of the A1 near the carotid artery origin, as would be used for an ACoA lesion, are preferred for distal ACA aneurysms located in the lower part of the A1 segment.11,15,18,26 The craniotomy may be modified so that a second aneurysm, which occurs more frequently than with lesions in other sites, can also be approached during the same operation. The interhemispheric approach, which is used for most distal ACA aneurysms, provides better bilateral exposure of the lesion than that achieved by the pterional and subfrontal approaches. The interhemispheric approach can be used to treat distal ACA aneurysms that are located at any site distal to the ACoA.

Distal ACA aneurysms are located predominantly at two sites: one is the PerA–CMA junction (32–86%), and the other is the origin of the FPA from the PerA (4–41%).3,6,8,10,11,17,18,22,24,26 The surgical approach for PerA–CMA aneurysms varies depending on whether the lesion is located above or below the corpus callosum. Supracallosal PerA–CMA aneurysms, which are situated above the level of the midportion of the genu of the corpus callosum, can be accessed anterosuperiorly with exposure of the distal ACA proximal to the aneurysm neck. On the other hand, infracallosal PerA–CMA aneurysms located below the level of the genu present more complex problems.

The CMA branches from the PerA at the PerA–CMA junction. In this study, we found that the mean angles of the distal and proximal infracallosal PerA to the CMA were 63.1 ± 33.1° and 131.9 ± 20.4°, respectively. These data indicate that in the infracallosal area, the angle of the CMA to the proximal PerA is always obtuse and the angle of the CMA to the distal PerA is always acute. Therefore, it is difficult to see the proximal PerA at the PerA–CMA junction from the superoanterior aspect. In addition, the proximal PerA runs almost parallel to the frontal cranial base. We found that the angle of the proximal PerA to the frontal cranial base was rather small (23.2 ± 18.1°) and that the PC point was 42.2 ± 15.9 mm from the nasion.

These findings demonstrate that there is only limited space in which to access the distal ACA aneurysms below the PC point and establish proximal control from the caudal direction along the frontal cranial base via the anterior interhemispheric approach, although the craniotomy may be further extended into the anteromedial part of the frontal base and nasal bone.25 On the other hand, when the approach is directed above the PC point, visualization of the PerA beneath the genu of the corpus callosum is difficult, possibly making it necessary to divide the anterior part of the corpus callosum to reach the aneurysm for dissection and clipping. The average thickness of the genu of the corpus callosum was 11.2 mm in this study.

Traynelis and Dunker22 reported that the anterior transcallosal approach provides excellent exposure of the proximal PerA and decreases the risk of uncontrolled intraoperative premature rupture. The advantage of the anterior interhemispheric approach below the PC point, compared with the approach above the PC point, is the ability it confers to access the lesion without performing an anterior callosotomy. It has several disadvantages, however, which include a narrow operative space, extension of the exposure into the frontal sinus, sectioning of the bridging veins, and more difficulty in dissecting between the frontal lobes and protecting the olfactory nerves.3,12,13,18,19 The anterior interhemispheric approach directed above the PC point is more likely to avoid the bridging vein than the approach directed below the PC point. The dissection between the frontal lobes may be easier above the PC point than below it, because the superior portion of the falx is wider above than below, thus reducing the extent of the interhemispheric adhesions between the frontal lobes. A disadvantage of the approach above the PC point is the difficulty in obtaining proximal control, which may require splitting of the genu of the corpus callosum. Nevertheless, corpus callosotomy for the treatment of epileptic disorders is an established procedure, and small anterior callosotomy rarely affects a patient’s normal activities.24

The approach to PerA–FPA aneurysms in the A1 segment is easier than that to PerA–CMA lesions. The mean angles of the proximal PerA to the FPA and the frontal cranial base were 77.7 ± 19.1° and 66.1 ± 23.3°, respectively. These findings indicate that the A1 segment of the distal ACA ascends steeply toward the A1–A2 junction and the FPA branches from the A2 segment almost vertically. The aneurysm complex, including the neck of the lesion and the proximal and distal arteries, could easily be seen when approached directly along the frontal cranial base.

Conclusions

In this study we demonstrate the detailed anatomical relationships of the infracallosal and A1 segments of the PerA to its branches, the CMA and FPA, which are the predominant sites of distal ACA aneurysms. The PC point is an important surgical landmark in planning the surgical strategy for infracallosal distal ACA aneurysms.

Acknowledgments

We thank Prof. Albert L. Rhoton, Jr., at the University of Florida for providing Dr. Kawashima with the opportunity to study in detail the microsurgical anatomy of the distal ACA. We also thank Ronald Smith, M.S., Director, and David Peace, M.S., Medical Illustrator at the Microneuroanatomy Laboratory, Department of Neurological Surgery, University of Florida, for constant support, as well as
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Becky Norquist and Laura Dickinson for preparation of the manuscript.

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Manuscript received February 4, 2003. Accepted in final form May 20, 2003. Address reprint requests to: Masatou Kawashima, M.D., Ph.D., Department of Neurosurgery, Neurological Institute, Graduate School of Medical Sciences, Kyushu University, Fukuoka, 812-8582 Japan. email: MasatouAzu@aol.com.