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A Simple Method to Estimate the Trajectory to the Genu of the Corpus Callosum in the Interhemispheric Approach for Distal Anterior Cerebral Artery Aneurysms

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Abstract

In the interhemispheric approach (IHA) for the distal anterior cerebral artery (DACA) aneurysms, the surgical trajectory to a DACA aneurysm is very important because surgeons sometimes encounter the intraoperative disorientation and the premature rupture. The purpose of this study was to clarify the anatomical landmarks indicating the trajectory to the genu of the corpus callosum (GCC) at the early stage of dissection for the correct intraoperative orientation. "Point A" was defined as the crossing point between the frontal bone and the line connecting the projected external acoustic opening (EAO) and the GCC on the midline slice of the sagittal three-dimensional computed tomography angiography (3D-CTA) images. We measured the distance from the nasion to Point A using midline sagittal slice images from 50 patients who underwent 3D-CTA at our institution. The average distance was 7.0 cm (±0.3 cm). Therefore, the direction of the spatula inserted in the direction of the EAO from Point A (7 cm above the nasion) corresponds to the trajectory to the GCC. In DACA aneurysms of the A3 segment, the pericallosal artery distal to the aneurysm can be safely identified by dissecting the interhemispheric fissure distal to the trajectory to the GCC. In DACA aneurysms of the A4 or A5 segment, the parent artery of the aneurysm can be safely identified by dissection along the trajectory to the GCC. Point A and the EAO can be used as landmarks indicating the trajectory to the GCC for the correct intraoperative orientation in the IHA for DACA aneurysms.

Keywords: interhemispheric approach, genu of the corpus callosum, distal anterior cerebral artery aneurysm

Introduction

Distal anterior cerebral artery (DACA) aneurysms are relatively rare and comprise approximately 5% of all intracranial aneurysms.[1–18] DACA aneurysms are usually operated on via the interhemispheric approach (IHA), because they mostly arise at the bifurcation between the callosomarginal and pericallosal arteries, which is usually located near the genu of the corpus callosum (GCC).[1,3,4,6,7,10,11,13,17,19–21] The surgical trajectory to DACA aneurysms is very important for safe clipping, because the medial frontal cortex covers DACA aneurysms until the final stage of dissection. As the anatomical positional relationship between a DACA aneurysm and the GCC can be confirmed using the preoperative sagittal three-dimensional computed tomography angiography (3D-CTA) images,[13,19,20,22] an estimation of the trajectory to the GCC at the early stage of dissection can provide the correct intraoperative orientation in the IHA. However, there are no established anatomical landmarks suitable for this purpose. Thus, the present study was performed to identify such landmarks and to indicate the strategy of approach to DACA aneurysms based on these landmarks. We investigated that the landmark point could be determined from the outside table before surgery.

The approach and the craniotomy for DACA aneurysms

DACA aneurysms can be located in various portions,[1,3,4,6,7,10,11,13,17,19–21] e.g., the A2 segment (7–27.8%

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of cases), A3 segment (59–83.8% of cases), and A4 or A5 segment or distal branch (5.4–22% of cases). The recommended operative approach for DACA aneurysmal clipping and the range of craniotomy depend on the location of the aneurysm. DACA aneurysms of the A3 segment, which is the most frequent location and most of which arise at the bifurcation between the callosomarginal and pericallosal arteries, have been further classified into three groups according to their positional relationship with the GCC, i.e., inferior A3 segment, anterior A3 segment, and superior A3 segment.[19,20,22] DACA aneurysms of the A3 segment are mainly treated via the anterior IHA.[1,3,4,6,10,11,13,19,20,22] However, DACA aneurysms of the inferior A3 segment, which are located on the proximal part of the A3 segment inferior to the GCC, may be treated via the basal IHA, because the genu will obstruct the neurosurgeon's view of the base of the aneurysm and prevent proper clip placement.[19,20,22] DACA aneurysms of the A2 segment are mainly treated via the basal IHA, which makes it possible to establish proximal control.[1,6,10,13,17–25] However, DACA aneurysms in the lower position of the A2 segment are occasionally treated via the pterional or subfrontal approach.[1,7,10,13,19,22] DACA aneurysms of the A4 or A5 segment or the distal branch are treated via the superior IHA.[1,4,6,7,10,13,18–20,22,26]

In the basal IHA, bilateral frontobasal craniotomy is usually performed.[1,6,10,13,17–25] In the anterior or superior IHA, unilateral frontal or parietal craniotomy is usually performed.[1,3,4,6,7,10,11,13,19,20,22] However, no matter which approach is selected, it is difficult to estimate the location of a DACA aneurysm accurately at the early stage of dissection with the IHA because there are no established anatomical landmarks other than exposing the parent artery or the branch connected to the aneurysm in a step-by-step manner. If a landmark, which is a point on the midline slice of sagittal view images within the craniotomy range that indicates the trajectory to the GCC based on a specific part of the face, can be identified, the strategy of approach to DACA aneurysms becomes more reliable.

Subjects and Methods

We retrospectively selected 50 random patients (age range, 38–82 years; mean age, 67.4 years; 17 males, 33 females) who underwent 3D-CTA for examination of an aneurysm at our institute from May 2013 to December 2016. We used sagittal 3D-CTA images to identify anatomical landmarks, as we call "Point A".

First, we defined the virtual external acoustic opening (EAO) projected on the midline slice of sagittal 3D-CTA images as the midpoint between the right and the left EAO projected on the midline slice including them both, because there was a slight deviation in the location of the right and left EAO on the sagittal images depending on the head position (Fig. 1A). Second, we defined "Point A" as the crossing point between the external surface of the frontal bone and the line connecting the projected EAO and GCC on the midline slice of sagittal 3D-CTA images (Fig. 1B). Third, we measured the distance from the nasion to Point A on the midline slice for each case (Fig. 1B). Finally, we investigated the usefulness of these anatomical landmarks to indicate the trajectory to the GCC through an intraoperative video image of a case with a DACA aneurysm.

The institutional review board and ethics committee of Hiroshima Prefectural Medical Association approved the study. Written informed consent was provided by all patients.

Results

The mean distance from the nasion to Point A was 7.0 cm (±0.3 cm) (Table 1). The measurement data of these 50 cases showed $p = 0.0835$ in the Shapiro–Wilk test, demonstrating that the data of these populations follow a normal distribution. The 95% confidence interval for this mean was 6.84 to 7.22 cm. In our institute, the range of frontal craniotomy in the sagittal direction is about 3–9 cm above the nasion in the anterior IHA for DACA aneurysms of the A3 segment (Fig. 1C). Thus, Point A is located approximately 1 cm behind the midpoint on the superior sagittal sinus observed in our craniotomy range. Therefore, if the spatula is inserted in the direction of the EAO from the surface of the interhemispheric fissure adjacent to Point A, i.e., 7 cm above the nasion, the GCC should be located in the deep portion on the extension of the spatula.

Case presentation

The case was a 60-year-old man who underwent clipping for a left middle cerebral artery bifurcation aneurysm 10 years earlier. He had a family history of subarachnoid hemorrhage. 3D-CTA revealed a 3.5 × 3 mm saccular aneurysm of the bifurcation between the callosomarginal and pericallosal arteries (A3 segment), projecting laterally. Sagittal 3D-CTA images confirmed the localization of the aneurysm on the GCC (Fig. 2A–2C).

Operative approach

The patient was placed in the supine position with the thorax elevated by 20° and the head fixed

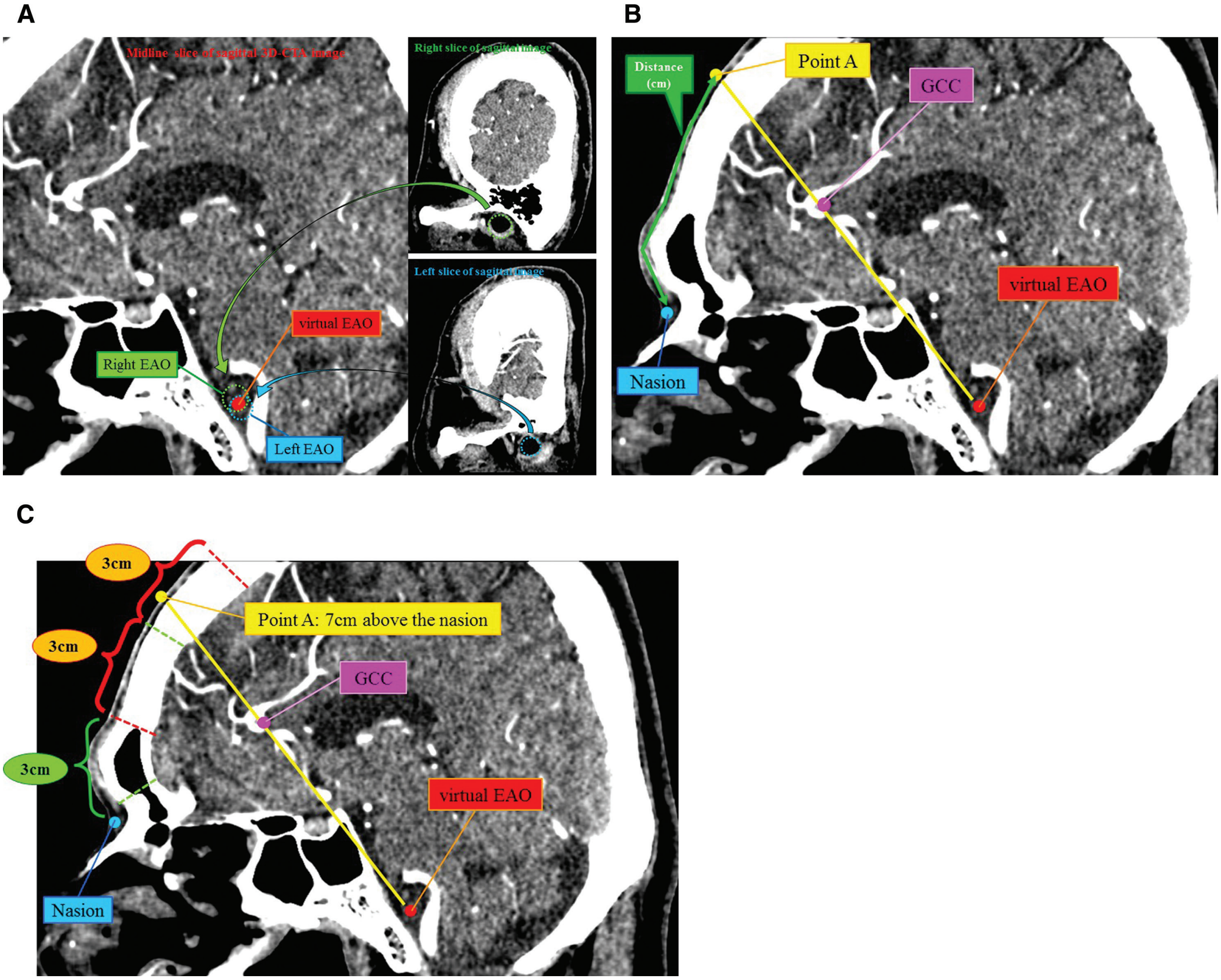

Fig. 1 (A) Definition of the virtual EAO projected on the midline slice of sagittal 3D-CTA images. The light green dotted circle shows the right EAO projected from the right slice onto the midline slice of the sagittal image. The light blue dotted circle shows the left EAO projected from the left slice onto the midline slice of the sagittal image. The virtual EAO projected on the midline slice of the sagittal image is defined as the red circle that is the midpoint between the light green and light blue dotted circles. (B) Definition of Point A on the midline slice of sagittal 3D-CTA images. The red circle shows the correct location of the EAO projected on the midline slice of the sagittal image. The purple circle shows the anterior edge of the GCC on the midline slice of the sagittal image. The yellow straight line shows the line connecting the projected EAO and the anterior edge of the GCC on the midline slice of the sagittal image. The yellow circle shows Point A at the crossing point between the external surface of the frontal bone and the yellow line on the midline slice of the sagittal image. The light blue circle shows the nasion on the midline slice of the sagittal image. The light green line shows the distance from the nasion to Point A on the midline slice of the sagittal image. (C) Positional relationship between the nasion, Point A, GCC, EAO, and the range of craniotomy on the midline slice of the sagittal image. Point A is located 7 cm above the nasion, i.e., 1 cm behind the midpoint on the midline in the range of craniotomy (red dotted lines) in the anterior IHA for a distal anterior cerebral artery aneurysm of the A3 segment at our institution. The light green dotted line shows the range of the craniotomy in the basal IHA for a distal anterior cerebral artery aneurysm. EAO: external acoustic opening, 3D-CTA: three-dimensional computed tomography angiography, GCC: genu of the corpus callosum, IHA: interhemispheric approach.

in the neutral position using three-point pinion fixation. We placed a marker on the EAO before draping (Fig. 2D), and then checked the location of the EAO through the drape and applied bone wax to that location after draping (Fig. 2E). A coronal skin incision was made behind the hairline, and the scalp flap was retracted toward the supraorbital ridge. A bilateral frontal craniotomy was performed

Table 1 Summary of the results

N	Age (years)	Sex	Distance from the nasion to Point A (cm)
1	52	F	6.9
2	71	M	7
3	70	F	6.8
4	65	F	6.9
5	70	F	6.8
6	81	F	6.8
7	82	F	7.2
8	71	M	6.8
9	78	F	7.2
10	73	M	7.2
11	48	M	6.6
12	79	M	7.2
13	63	F	7.6
14	74	M	7.3
15	45	M	7.7
16	68	M	7.3
17	80	F	7.1
18	56	F	6.8
19	66	F	6.5
20	66	F	7.2
21	75	F	7
22	76	F	7.2
23	72	F	7
24	77	F	6.5
25	75	F	6.7
26	76	F	6.8
27	56	F	7.1
28	73	F	6.8
29	71	F	6.8
30	45	F	7.1
31	61	M	7.2
32	73	M	6.8
33	64	M	7.1
34	42	M	7.5
35	38	M	6.8
36	74	F	7
37	74	F	7.1
38	59	F	7.2
39	71	F	7.5
40	60	M	7.2
41	60	M	7.8
42	79	F	6.8
43	78	F	7.2
44	81	F	7.3
45	73	F	7.3
46	71	F	6.5
47	75	F	7.1
48	65	M	6.5
49	58	M	6.9
50	60	F	7

F: female, M: male, N: number.

mainly on the right side in the range of 3.5–9 cm above the nasion in the midline and approximately 4 cm laterally on the right side to avoid opening the frontal sinus. The dura was opened from outside to the midline, taking care not to damage the bridging veins that drain into the superior sagittal sinus. These ascending superior frontal veins crossing the surgical field were dissected carefully and mobilized from the frontal cortex to avoid stretching or impairment of the venous drainage.

Point A was identified at 7 cm above the nasion in the midline and 0.75 cm behind the midpoint on the superior sagittal sinus observed in the craniotomy range (Fig. 2F). The left spatula was inserted in the direction of the EAO from the surface of the interhemispheric fissure adjacent to Point A (Fig. 2E and 2G). Dissection of the interhemispheric fissure was started from the distal part of the GCC and proceeded safely to the proximal part using the direction of the left spatula as an indicator of the trajectory to the GCC (Fig. 2H). Although we changed the position and direction of both spatulas according to the steps of the dissection, we could reinsert the left spatula in the direction of the EAO from Point A when we needed to confirm the trajectory to the GCC. The bilateral callosomarginal and pericallosal arteries were exposed carefully from the distal to proximal portion in a step-by-step manner (Fig. 2I), and the GCC was recognized in the deep portion on the extension of the left spatula inserted in the direction of the EAO from Point A (Fig. 2J). The dome of the aneurysm extended into the right cingulate gyrus. The right A2 segment was exposed through the space between the right A3 segment and the GCC. The dome and neck of the aneurysm were exposed sufficiently and clipped safely (Fig. 2K). In this way, the trajectory to the GCC that was indicated by Point A based on the EAO provided the correct intraoperative orientation at the early stage of dissection, and Point A was within the range of craniotomy. Therefore, Point A, which is located at 7 cm above the nasion on the midline, can be utilized as a landmark that indicated the trajectory to the GCC based on the EAO, at least in the IHA for DACA aneurysms of the A3 segment.

Discussion

The incidence of DACA aneurysms is low, approximately 5% in the reviewed literature.[1–18] DACA aneurysms are usually operated on via the IHA, and these aneurysms present surgeons with some unique problems including the narrowness of the interhemispheric fissure and callosal cistern with the possibility of strong adherence with the cingulate gyri, the difficulty in establishing proximal control due to the anatomical relationship between the proximal A2 segment and GCC, adherence of the aneurysmal dome to the cingulate gyrus, and projection of the aneurysmal dome toward the surgeon, which may cause premature rupture due to the inadvertent retraction of the frontal lobe.[8,22,26,27] In addition, DACA aneurysms can be located in various portions,[1,3,4,6,7,10,11,13,17,19–21] e.g., the A2 segment, A3 segment, and A4 or A5 segment or distal branch. Therefore, it is very important to identify the surgical trajectory to DACA aneurysms to prevent intraoperative disorientation and premature rupture.

The trajectory to the GCC can provide correct intraoperative orientation at the early stage of dissection in the IHA for a DACA aneurysm, because the anatomical positional relationship between the aneurysm and GCC can be confirmed through the preoperative sagittal 3D-CTA images, especially for A3 segment aneurysms.[13,19,20,22] In this study, we suggested Point A and the EAO as convenient landmarks to indicate the trajectory to the GCC. Point A is located about 7 cm above the nasion on the midline, which seems suitable for Japanese patients. Indeed, this study has a limitation and our patients subpopulation may not represent the characteristics of Japanese as a whole. However, we thought that this measured mean value can be used as a reference.

In the anterior IHA for DACA aneurysms of the A3 segment, the first step is the identification of the pericallosal artery distal to the aneurysm. For corresponding to the trajectory to the aneurysm, the operator should first proceed the dissection of the interhemispheric fissure distal to the trajectory to the GCC. The second step is the dissection of the pericallosal artery from the distal to the proximal portion of the aneurysmal neck, the rupture

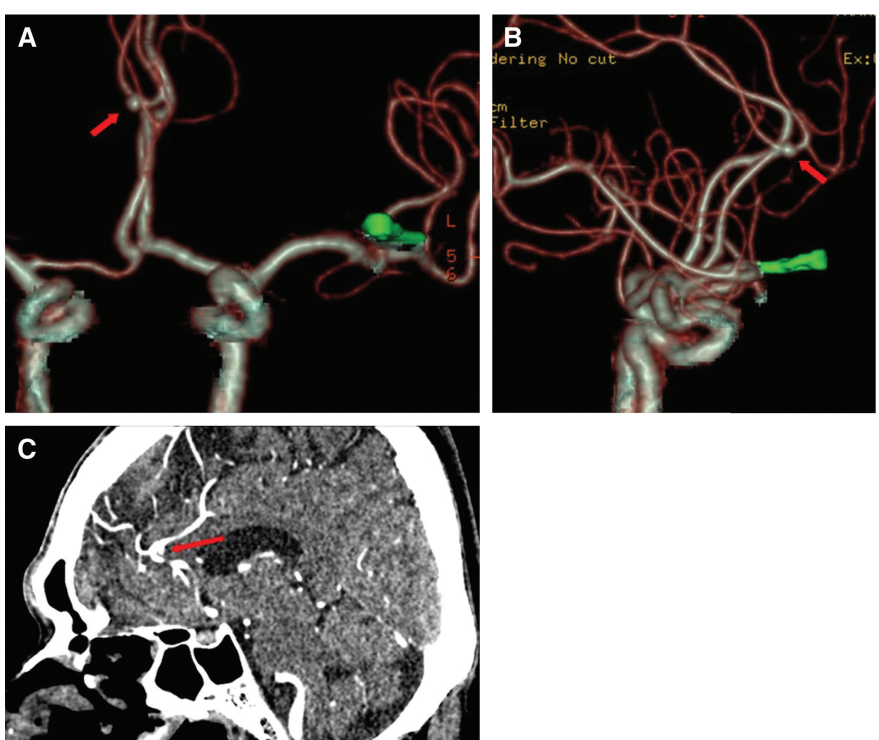

Fig. 2 (A–C). Preoperative 3D-CTA images and sagittal image. (A and B) 3D-CTA demonstrated a 3.5 × 3 mm saccular aneurysm of the right bifurcation between the callosomarginal and pericallosal arteries, projecting laterally. (C) The sagittal 3D-CTA images confirmed the localization of the aneurysm on the GCC.

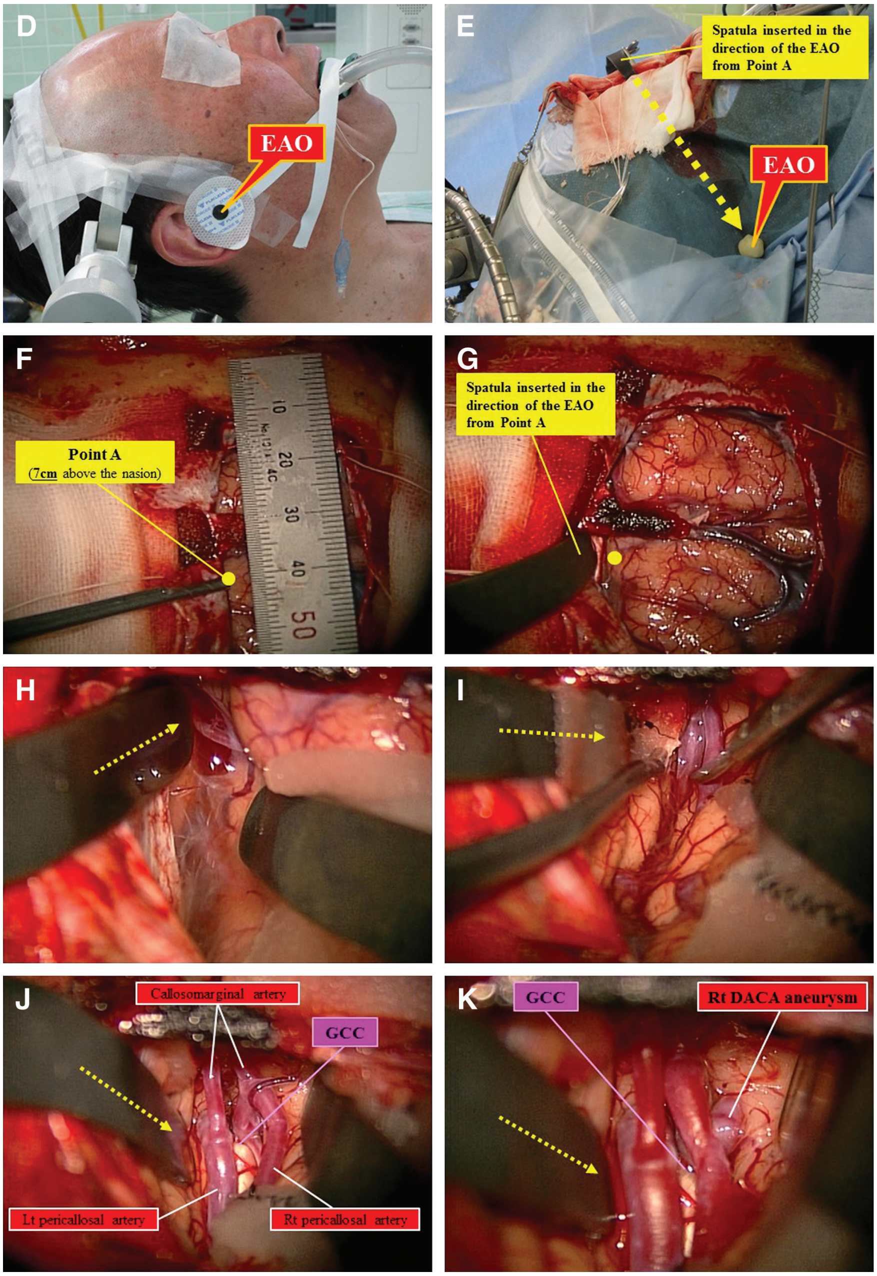

Fig. 2 (Continued) (D–K) Operative findings in the anterior IHA for a 60 year-old male patient with an unruptured right distal anterior cerebral artery aneurysm. (D) A marker was put on the EAO before draping. (E) Bone wax was put on the location of the EAO after draping. (F) Point A was defined as a point located 7 cm above the nasion in the midline. (G) The left spatula was inserted in the direction of the EAO from Point A. (H) Dissection of the interhemispheric fissure proceeded from the distal to proximal part. (I) The bilateral pericallosal arteries were exposed from the distal to proximal portion in a step-by-step manner. (J) The bilateral callosomarginal arteries were exposed, and the GCC was located in the deep portion on the extension of the left spatula. The right A2 segment was exposed through the space between the right A3 segment and GCC. (K) The right DACA aneurysm, whose dome extended into the right cingulate gyrus, was exposed after securing the right A2 segment. The yellow dotted arrow from Point A to the EAO indicates the estimated trajectory to the GCC. Rt: right, Lt: left, 3D-CTA: three-dimensional computed tomography angiography, GCC: genu of the corpus callosum, IHA: interhemispheric approach, EAO: external acoustic opening, DACA: distal anterior cerebral artery.

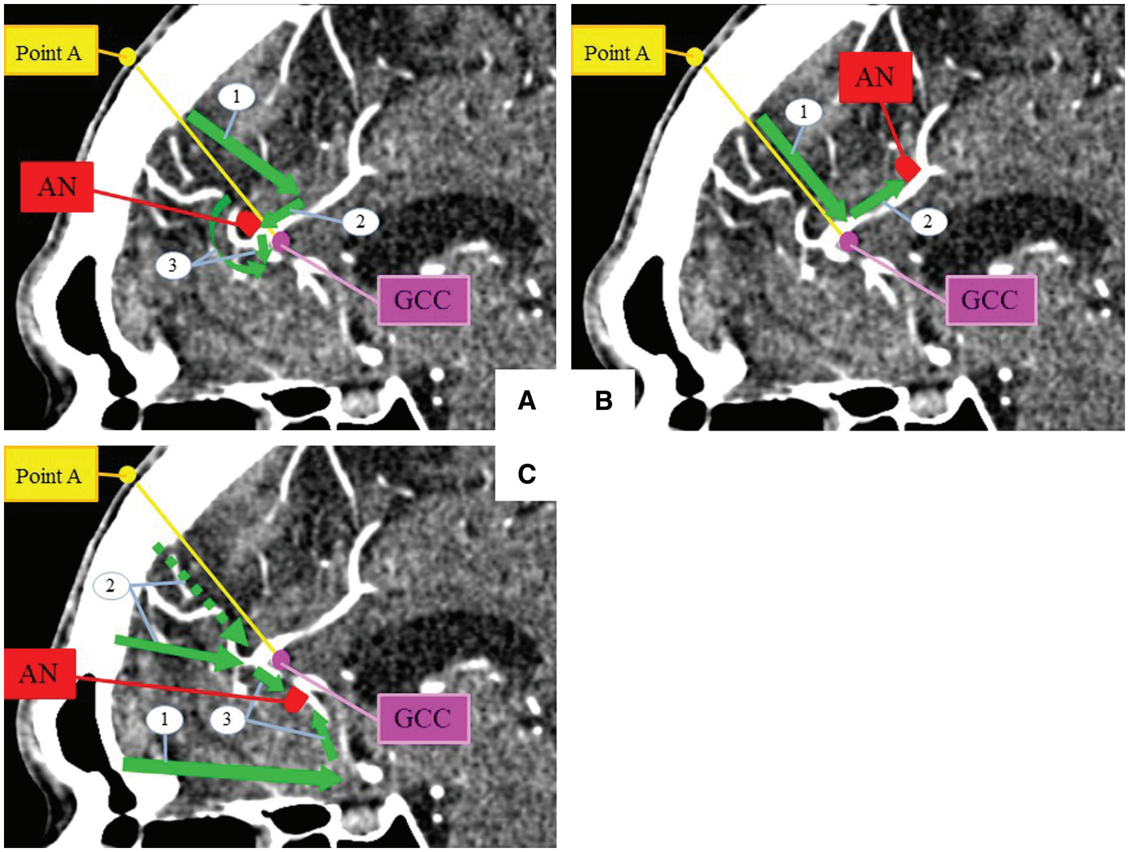

Fig. 3 The procedure of the dissection in the IHA for DACA aneurysms. (A) The anterior IHA for DACA aneurysms of the A3 segment. ① Identify the pericallosal artery distal to the aneurysm. ② Dissect the pericallosal artery from the distal to the proximal portion of the aneurysmal neck. ③ Expose the parent artery (A2) by dissecting around the aneurysmal neck or the callosomarginal artery. (B) The superior IHA for DACA aneurysms of the A4 or A5 segment. ① Identify the parent artery of the aneurysm by dissecting along the trajectory to the GCC. ② Dissect from the proximal to the distal portion of the aneurysm. (C) ① Expose the anterior communicating artery complex for the proximal control. ② Identify the A2 segment distal to the aneurysm along the empirical direction (green arrow) or the trajectory from Point A to the GCC (green dotted arrow). ③ Dissect in the three-step fashion described by Ito. Green arrows show the trajectory of the dissection. AN: aneurysm, GCC: genu of the corpus callosum.

point of which may adhere to either the left or right CG or protrude to the interhemispheric fissure. In the process of these dissections, the trajectory to the GCC seems to be a good landmark for getting the correct distance and direction to the aneurysm, which causes the safe dissection around the aneurysm. To apply the tentative clip, the operator should expose the neck and dome of the aneurysm as much as possible avoiding the rupture point, and then the parent artery (A2) can be clearly seen in many cases. If it is difficult to expose the parent artery, the additional dissection around the aneurysm or of the interhemispheric fissure along the callosomarginal artery from the distal to the proximal portion of the aneurysm should be made (Fig. 3A).

In the superior IHA for DACA aneurysms of the A4 or A5 segment, the first step is the identification of the parent artery of the aneurysm for easy and safe procedure of dissection along the trajectory to the GCC. The second step is the dissection from the proximal to the distal portion of the aneurysm (Fig. 3B).

In the basal IHA for DACA aneurysms of the A2 or inferior A3 segment, the first step is the exposure around the anterior communicating artery complex for the proximal control. The second step is the dissection of the A2 segment from the proximal to the distal portion of the neck of the aneurysm. However, if it is very difficult to dissect an anterior interhemispheric fissure from the proximal to the distal portion, the anterior interhemispheric dissection should eventually be proceeded in the three-step fashion described by Ito[28,29] in order to expose the aneurysm. In this procedure, the trajectory to the GCC may be a good landmark to identify the A2 segment distal to the aneurysm, especially for inexperienced young neurosurgeons (Fig. 3C).

However, the range of craniotomy depends on the approach for DACA aneurysms. In the basal IHA, bilateral frontobasal craniotomy is usually perf ormed.[1,6,10,13,17–25] In the anterior or superior IHA, unilateral frontal or parietal craniotomy is usually performed.[1,3,4,6,7,10,11,13,19,20,22] Actually, the exact range of craniotomy depends on the practices of each institution. In our institute, the range of craniotomy in the sagittal direction in the IHA for DACA aneurysms was decided as follows: 6 cm above the nasion in the basal IHA, 3–9 cm above the nasion in the anterior IHA (The exact range of craniotomy is determined by preoperative 3D-CT bone images to avoid opening the frontal sinus.), and in a case-by-case manner in the superior IHA (In almost cases, point 7 cm above the nasion is included in the range of craniotomy.) (Fig. 1C). Therefore, in the anterior and superior IHA for DACA aneurysms, Point A can be utilized as a landmark on our range of craniotomy. However, in the basal IHA for DACA aneurysms, Point A may locate outside the range of craniotomy, so extending craniotomy is necessary in the sagittal direction above Point A in order to utilize these landmarks.

Indeed, there have been some reports on the usefulness of various imaging devices, such as a navigation system and ultrasound devices, for estimating the intraoperative anatomical location of DACA aneurysms in the IHA.[30–34] However, our method is also useful and very convenient to obtain the correct intraoperative orientation in the IHA for DACA aneurysms.

Conclusion

In the IHA for DACA aneurysms, estimating the trajectory to the GCC at the early stage of dissection by our method could easily identify the correct intraoperative orientation and increase surgical safety.

Conflicts of Interest Disclosure

The authors report no conflicts of interest concerning the materials or methods used in this study or the findings specified in this paper.

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