

Current Management of Mirror Distal Anterior Cerebral Artery Aneurysms in Association with Multiple Aneurysms: Case Report with Literature Review

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Key words

- Computational flow dynamic (CFD)
- Distal anterior cerebral artery (DACA)
- Kissing
- Mirror
- Multiple aneurysms
- Pericallosal

Abbreviations and Acronyms

A2/A3 DACA: A2/A3 segment of distal anterior cerebral artery

CFD: Computational fluid dynamics

CT: Computed tomography

DACA: Distal anterior cerebral artery

WSS: Wall shear stress

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INTRODUCTION

Intracranial aneurysms are a common vascular disorder, with a prevalence from 0.9% to 10%,^{1,2} yet the exact frequency and cause of mirror aneurysms are still unknown. A possible genetic hereditary correlation was found in relation to multiple intracranial aneurysms, with an incidence of 40%.^{3,5} In the case of subarachnoid hemorrhage, the incidence varies from 15% to 35%.^{4,6–10} Bilateral pericallosal aneurysms are extremely rare and represent the least incidence of all intracranial aneurysms.¹¹ Komiyama et al. reported that “kissing” aneurysms occurred in 0.9% of

■ **BACKGROUND:** Mirror aneurysms represent 2 adjacent arterial protrusions. Although the size is considered a major risk factor in terms of rupture, sometimes it is the smaller aneurysm that ruptures. Here, we present the contemporary management of mirror distal anterior cerebral artery (DACA) aneurysms associated with multiple aneurysms. Computational fluid dynamic (CFD) analysis was performed when assessing multiple aneurysms using Hemoscope, version 2015.

■ **CASE DESCRIPTION:** Among multiple aneurysms, a mirror A2/A3 DACA aneurysm was found in a single patient. Surgical treatment was provided for all aneurysms through a single-stage procedure. The left ruptured A2/A3 aneurysm was smaller compared with the right (7.5 × 3.5 mm/10.8 × 3.2 mm). CFD showed greater wall pressure (WP) in the left ruptured A2/A3 aneurysm (left A2/A3 WP 84,000–84,402 Inst. mm Hg/right A2/3 WP 84,224–84,315). WP in the left middle cerebral artery and anterior communicating artery aneurysms showed lesser values compared with the ruptured aneurysm (WP upper values 84,361 and 84,367, respectively). Wall shear stress showed low values for all aneurysms with the lowest flow rate values in the left A2/A3 aneurysm.

■ **CONCLUSIONS:** In cases of ruptured mirror aneurysms followed by the presence of intracerebral hematoma, surgery is considered the primary option with the best results. A one-stage dual craniotomy procedure was found safe in the associated treatment of other multiple aneurysms. At present, the size of the aneurysm, the hemodynamic influence, and the local configuration are all considerations during the preoperative assessment of multiple aneurysm cases. According to our knowledge, this article presents the first CFD analysis of mirror DACA aneurysms associated with aneurysm multiplicity.

their series, whereas Yaşargil et al. and Sun et al. noted a prevalence of 0.2%.^{12–14} Mirror aneurysms in general are more frequent and usually larger in female compared with male patients.¹⁰

Distal anterior cerebral artery (DACA) aneurysms are located on the A2–A5 segments of the anterior cerebral artery.¹⁵ They are usually present in the form of subarachnoid hemorrhage and a “flame-shaped” hematoma on computed tomography (CT) scans. Furthermore, DACA bilateral aneurysms are a very rare phenomenon, and we only found a limited number of reports in the official literature.^{3,16–34} The position and the difficulty in accessing the area, the

narrow working space, and the possibility of associated hematoma make both surgical and endovascular treatment of these aneurysms challenging.^{24,35} A lack of preoperative imaging has led to many misdiagnoses of this type of aneurysm in the DACA region.³⁵

CASE REPORT

A female patient aged 49 years suffering from headache, vomiting, and neck stiffness was admitted to the emergency department. She had a Glasgow Coma Scale score of 14 and a Hunt and Hess score of 3. CT scan confirmed subarachnoid hemorrhage, blood in the ventricles, and showed a “flame-shaped”

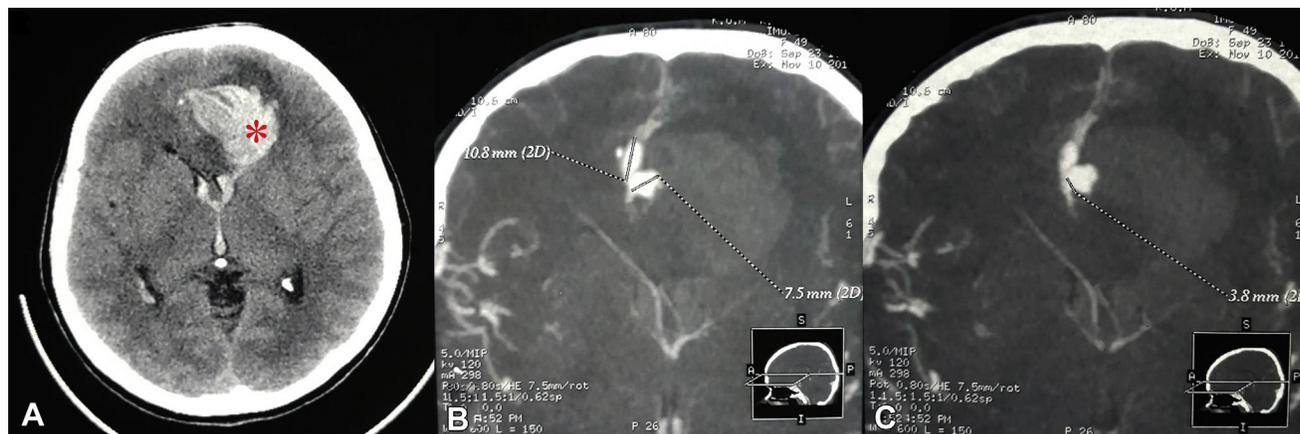


Figure 1. (A) Computed tomography (CT) scan from the emergency department showing the left-sided intracerebral and collosal hematoma with intraventricular hemorrhage. *Red asterisk* indicates intracerebral hematoma. (B–C) Two-dimensional CT angiography with associated

intracerebral hematoma. The measurements of the length and neck sizes of the aneurysm are shown. (B) Length of the A2/A3 right is 10.2 mm, and the length of the left A2/A3 is 7.5 mm. (C) The neck of the left A2/A3 aneurysm is 3.8 mm.

intracerebral hemorrhage dominantly on the left side (Figure 1).

Three-dimensional CT angiography showed multiple aneurysms: the left middle cerebral artery, anterior communicating artery, and bilateral A2/A3 segment of distal anterior cerebral artery (A2/A3 DACA) aneurysms in the mirror position. Digital subtraction angiography was performed to clarify and assess the anatomy and morphology of the aneurysms (Figure 1). The patient underwent microsurgical clipping as an ipsilateral one-stage dual craniotomy procedure. A left parasagittal craniotomy was performed

followed by a left pterional craniotomy (Figure 2).

The postoperative period was uneventful, and early postoperative CT showed regression of the intracerebral hematoma and multiple titanium clips in place of previous aneurysmal protrusions (Figure 3A–B). After 14 days of postoperative care, the patient was discharged from the hospital fully conscious and without any neurologic deficit (modified Rankin Scale score 0). Follow-up digital subtraction angiography conducted 2 years after the surgery showed complete occlusion of all aneurysms with satisfactory distal blood flow (Figure 3C–D).

Hemodynamic analysis (computational flow dynamics [CFD]) was performed post-factum to compare the presented aneurysms. The Hemoscope, version 2015 (EBM Co., Ltd., Tokyo, Japan) program was used to calculate the diameter of the vessels and their flow rates against the preoperative 3-dimensional CT angiography. The comparative data and images are presented in Table 1 and Figures 4–9.

LITERATURE DATA REVIEW

A total of 21 different information sources reporting on 29 cases from 1974 up until

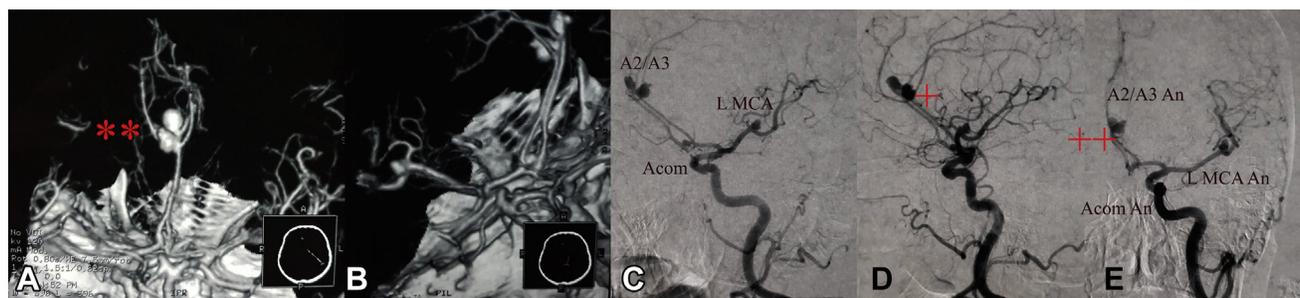


Figure 2. (A–B) Three-dimensional computed tomography angiography showing the anteroposterior (AP) and oblique view and multiple aneurysms, including the left middle cerebral artery (MCA), anterior communicating artery (ACoA), and the bilateral kissing A2/A3 distal anterior cerebral artery (DACA) aneurysms in the mirror position. The intraoperative left A2/A3 aneurysm is ruptured. (C) Preoperative digital subtraction angiography (DSA) in the oblique view and multiple intracranial aneurysms in the projection of both the A2/A3 DACA and ACoA and the left MCA. (D) DSA lateral view with the “chou cho” appearance of both A2/A3 DACA

marked with + and ++ (Latin pronunciation of the Japanese word for butterfly; Bosnian - Leptir). (E) Preoperative DSA, AP view. Multiple aneurysms are marked. A “chou cho” appearance of the kissing DACA in the mirror position is noted on the AP scan. *Red asterisks* indicate kissing A2/A3 aneurysms in the mirror position; A2/A3 kissing aneurysms in the A2/A3 segment of the DACA in the DSA scans (lateral and AP); ACoA, An unruptured ACoA aneurysm location in the DSA scans; L MCA, an unruptured left MCA aneurysm in the DSA (lateral and AP); + and ++, a “chou cho” sign on the DSA.

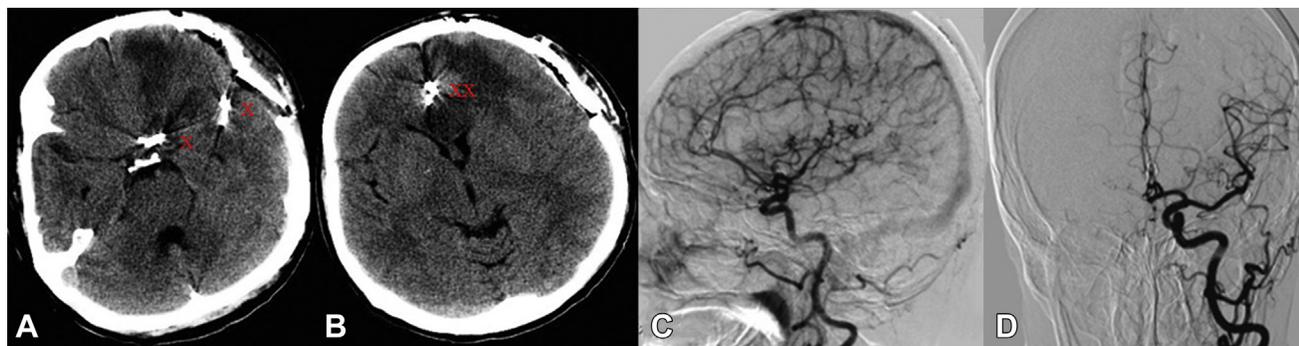


Figure 3. (A) Postoperative computed tomography scan showing the patient's condition after the left pterional craniotomy. Multiple clips are seen in the projection of the left middle cerebral artery and anterior communicating artery (ACoA). (B) Clips at the location of both previous A2/A3 aneurysmal necks are shown. There is no residual intracerebral hematoma on the left side. Note the size of the ventricle, with no sign of

hydrocephalus. (C) Follow-up digital subtraction angiography (DSA; 2 years after surgery—lateral view) showing no residual aneurysms and sufficient distal blood flow. (D) Follow-up DSA (2 years after surgery—anteroposterior view) showing no residual aneurysms and sufficient distal blood flow. The red × marks the clip placed at the position of the previous ACoA aneurysm. The red × × marks 2 clips placed in both the A2/A3 aneurysms.

2019 were consulted.^{3,16-34} The standard PubMed literature search included multiple words such as kissing (mirror aneurysms), DACA kissing (DACA mirror), pericallosal kissing (pericallosal mirror), DACA aneurysms (pericallosal aneurysms), treatment DACA aneurysms, and treatment pericallosal aneurysms. A summary of the available data analyzed is contained in **Table 2**. The 29 patients in the 21 studies refer to mirror or kissing aneurysms in the DACA region. There is a slight prevalence of female patients (17 or 58.62% female and 12 or 41.37% male). The medical history of these patients is presented in **Table 2**. All of the patients presented had bleeding except for one. Of these patients, 23 or 79.31% were related to subarachnoid hemorrhage. Other forms of bleeding were present in a single patient, as shown in **Table 2**. Precise locations for the aneurysm were given for the DACA or pericallosal artery in 24.13% of cases (**Table 2**). Surgical treatment was selected for 82.75% of the patients, coil embolization for 6.89%, and observation assigned for 3.44% of the patients, whereas a single patient was treated through a combination of surgery and observation.

DISCUSSION

Mirror and kissing aneurysms are a rare type of multiple aneurysm, first described by Jefferson in 1978.³⁶ However, the exact prevalence remains unknown. Published articles show in general that

from 4% to 40% of patients with multiple aneurysms involve mirror aneurysms.⁴⁻¹⁰ In this review, only 8 studies showed DACA mirror aneurysms with multiplicity.^{3,11,17,22,25-27,29} The causes and risk factors of mirror aneurysms remain unknown except for certain congenital predispositions (Marfan syndrome, Ehlers–Danlos syndrome, autosomal-dominant polycystic kidney disease, and pseudoxanthoma elasticum).^{32,36} Weil et al.³⁷ reported multiple aneurysms in identical twins, and 1 study found 10 aneurysms in a single patient. The latter study reported a deficiency of factor VII as a possible cause linked to some genetic disorder.³

In the present case report, none of the respondent patients or relatives reported any family history of systemic disease. Compared with other locations, DACA aneurysms are more prone to the presence of bleeding. According to our results, we found subarachnoid hemorrhage present in 22, and other sources of bleeding were found in 4 cases.

Different studies hypothesize that an embryological, pre-existing defect of specific arterial segments could be the reason for the development of mirror aneurysms.^{38,39} One study lists smoking and hypertension among the risk factors,⁴⁰ whereas some reports cited a decrease in the body mass index as a factor of aneurysm growth.⁴¹ Recently, Huang et al.⁴² proposed that the increasing incidence of mirror aneurysms could be associated with a family history of

hyperlipidemia. In regard to the pathogenesis of bilateral aneurysms, previous reports suggest that symmetry between congenital anatomic defects and hemodynamic stress is a potential cause.⁴³ It also has been suggested that the supreme anterior communicating artery is susceptible to the growth of bilateral DACA aneurysms.²⁴ Other studies suggest a relationship between location and rupture.⁴⁴ Grochowski et al.⁴¹ highlighted the location of an aneurysm as a factor for predicting rupture and that if correlated with location, the size of an aneurysm is important. However, the majority of the reviewed articles had insufficient data on the size of aneurysms.^{11,16,17,20-23,26-31,34}

What is interesting in the illustrated case of a ruptured left A2/A3 DACA is the fact that the medium-sized left DACA ruptured, whereas the right one, which refers to a large aneurysm, did not. In addition to size, the shape, anatomic variations, and local hemodynamic also should be considered.

Hemodynamics

Different local flow conditions in differently located arteries could be an important factor in the development of an aneurysm.⁴⁵ Many studies cite the influence of hemodynamic stress as a risk factor in relation to possible rupture. Doddasomajula et al.⁴⁶ studied wall shear stress (WSS), inflow jet, and intra-aneurysmal flow patterns in cases of mirror aneurysms in the same patient. The results show that the distribution of oscillatory WSS

Table 1. Summary of CFD Results for the Right and Left A2/A3, the Left MCA, and the ACoA Aneurysms

CFD Parameters	Left A2/A3		Right A2/A3		Left MCA			ACoA		
Diameter median, mm	1.6	1.2	1.6	1.4	2.9	2.0	2.6	2.2	1.6	2.2
Diameter min/max, mm	1.6/1.6	1.2/1.2	1.6/1.6	1.4/1.4	2.9/2.9	2.0/2.0	2.6/2.6	2.2/2.2	1.6/1.6	2.2/2.2
Length, mm	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2
Surface, mm ²	0.9	0.8	0.8	0.9	1.5	1.0	1.4	1.0	0.9	1.0
Volume, mm ³	0.3	0.2	0.3	0.3	1.1	0.5	0.9	0.5	0.3	0.6
Flow rate, mL/min	9	8	10	9	51	15	35	22	6	16
Flow rate CA, mL/min	9	8	10	9	51	15	35	22	6	16
Flow rate PS, mL/min	15	14	16	15	84	26	57	37	10	27
Flow rate ED	6	6	6	6	35	11	24	15	4	11

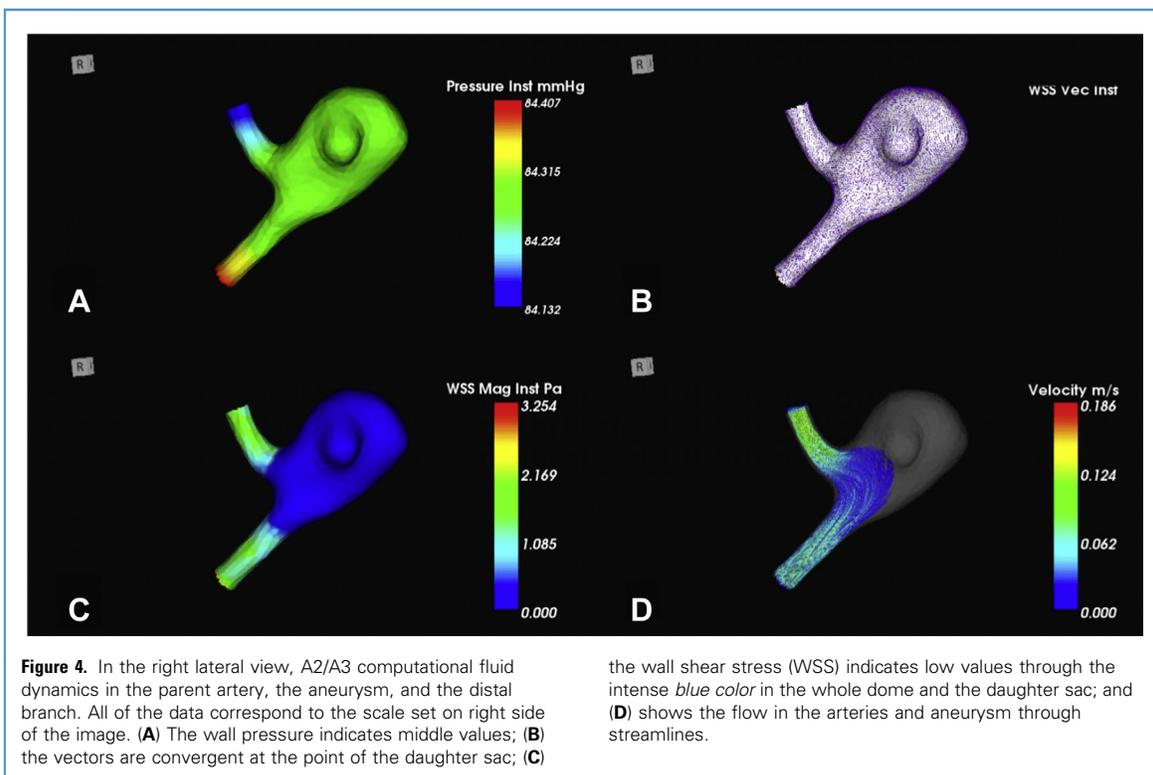
CFD, computational fluid dynamics; MCA, middle cerebral artery; ACoA, anterior communicating artery; CA, cerebral aneurysm; PS, peak systole; ED, end diastole.

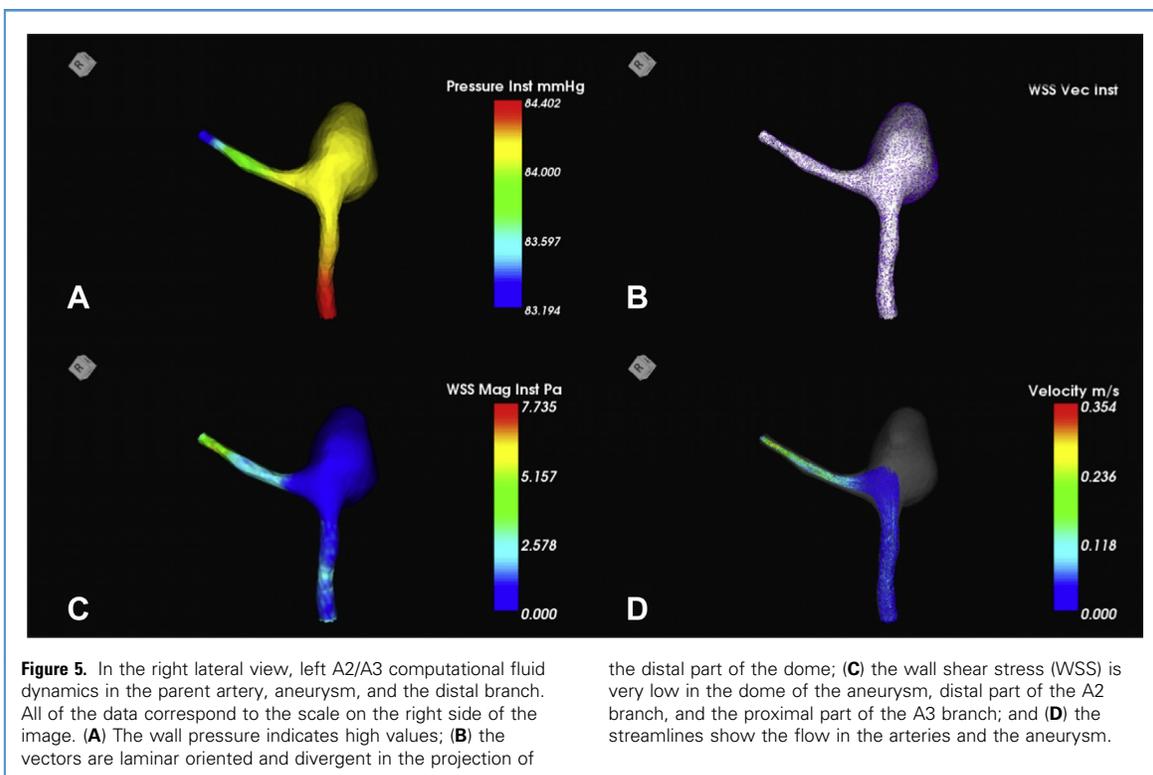
(oscillatory index max) was greater in ruptured compared with unruptured and that the arteries were more elongated. Another study found a greater aspect ratio, lower WSS, and mean oscillatory index in the ruptured group. According to the analysis, there is a strong correlation between the risk of rupture, the size of the aneurysm, and the local fluid

dynamics in the aneurismal dome.⁴⁷ In accordance with previous reports, the present study found that CFD measurement could be of paramount importance because WSS is recognized as the most independent factor of potential aneurysm rupture, especially if the large area of the aneurysm is included.^{41,44} Meng et al.⁴⁸ report the

influence of both high and low WSS according to the heterogeneity of the aneurysm pathophysiology.

The basic CFD analysis of the illustrative case showed differences between the left and right A2/A3 aneurysms. The WSS was very low for each aneurysm what seems to impend possible aneurysm rupture (Figures 4C, 5C, 8A–B). WSS in

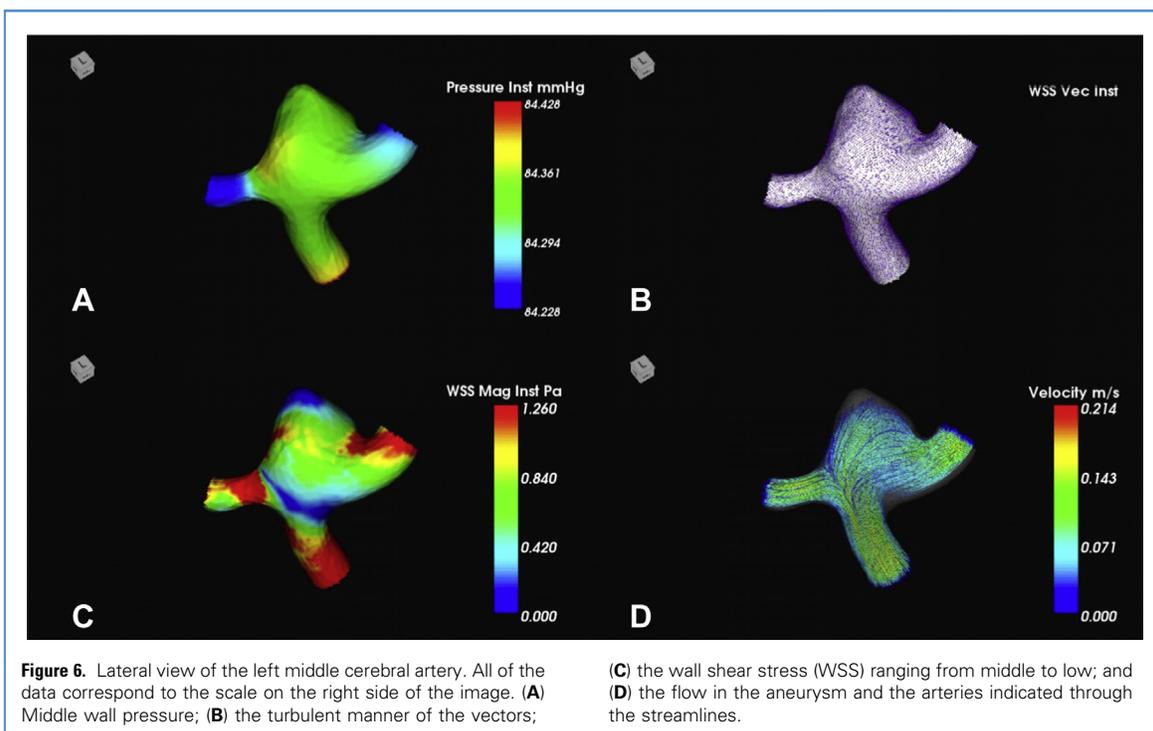


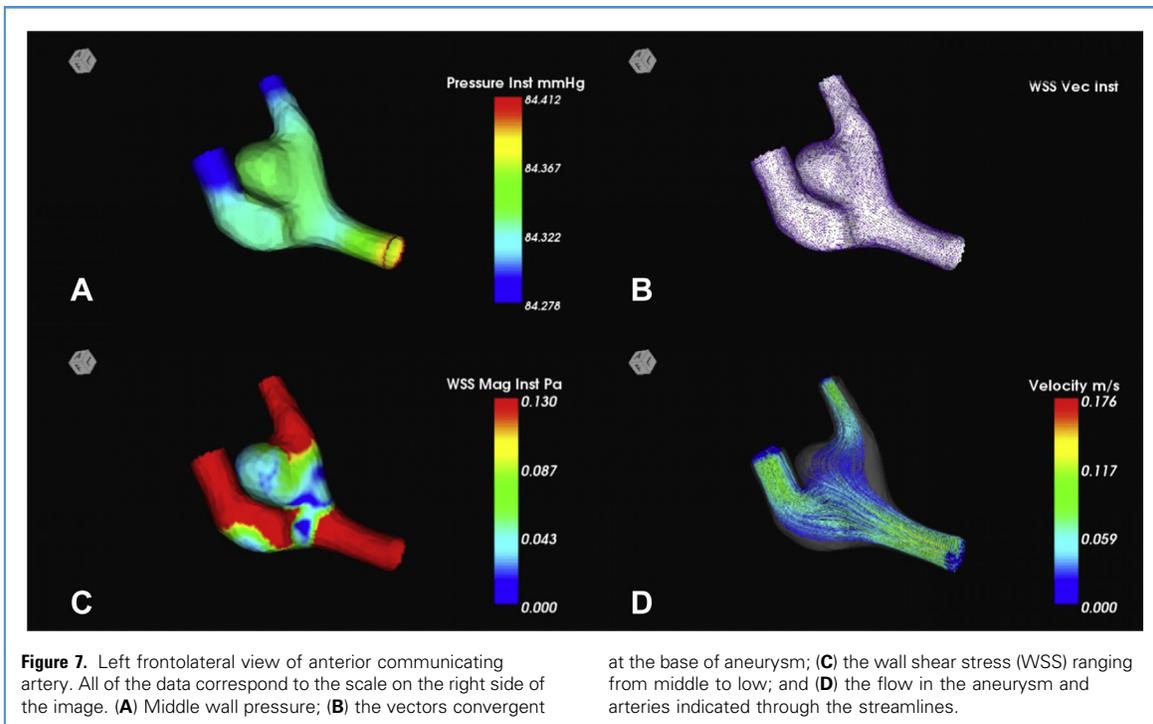


the left middle cerebral artery and anterior communicating artery also showed lesser values with a different range of colors in

scale (**Figures 6C** and **7C**). The main question is why the left A2/A3 aneurysm ruptured but the larger right A2/A3 did

not. One previous study of 10 aneurysms in a single patient with triple mirror aneurysms, including DACA, showed





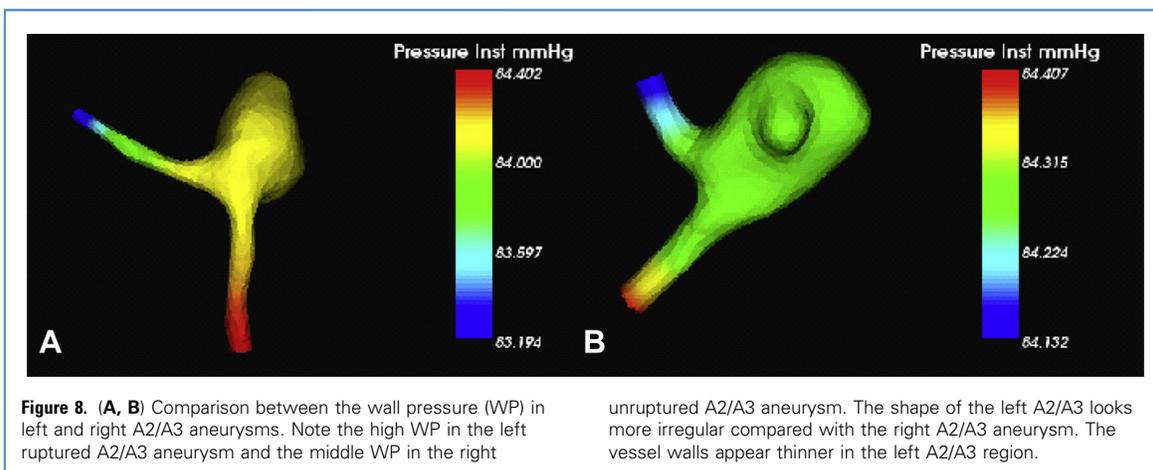
Fisher grade 4 subarachnoid hemorrhage on CT scans.³ Even bilateral DACA was not found as the largest among the 10 aneurysms; it seems one of those had ruptured. The same study could not explain the correlation between mirror aneurysms and the hemodynamics.³

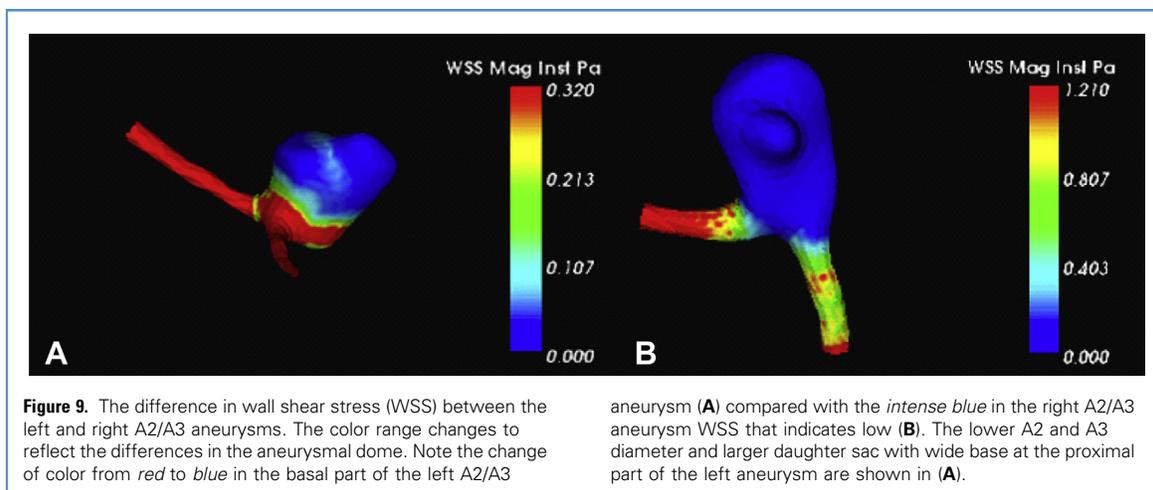
The present study noted differences in wall pressure and vector orientation between both A2/A3 aneurysms in our case. In the left A2/A3 aneurysm, the wall pressure was very high whereas the right A2/A3 showed middle values of wall pressure on the scale of ranges

(Figures 4A, 5A, 8A–B; Figures 4B and 5B). The fact that the wall pressure was greater in the left A2/A3 aneurysm along with the vector divergence could partially highlight local dome flow in rupture site assessment. However, the diameter of the left A2/A3 was found to be lower in the A3 according to the right A3 segment followed by a decrease in flow (diameter min/max [mm]: 1.2/1/2, 1/4, 1/4, flow rate mL/min = 8 and 9, respectively). Associated vasospasm and more blood on the left side were considered possible influential factors for lower flow rate in

the left A2/A3. Considering both M2, the flow rate was found to be much greater (flow rate mL/min: 15/35) and the diameter of the vessels larger compared with the A2/A3 segment (diameter median mm: 2.0/2.6). It is possible that the anatomic differences in those segments could be the cause.

However, certain facts should be considered in relation to the presented case. The CT and the CFD analysis were performed in different centers and at different times. Hemodynamic software provides a close and precise view of the





configuration of the aneurysm. We found during the CFD analysis that the shape of the left A2/A3 aneurysm was irregular with a wider middle section compared with the dome and neck. The right-side midline shift could have influenced the result because of the left frontal hematoma. Furthermore, the bigger daughter sac and more irregular shape was found in the ruptured A2/A3 compared with the right one (Figure 9A). Considering the interest in recent cerebral hemodynamic and the current lack of data, future comprehensive analysis of a large sample of multiple aneurysms associated with the mirror type could provide more answers about the influence of distal flow. To recognize and treat mirror cases in time, the need for more precise data should be addressed through earlier diagnosis. To the best of our knowledge, this article is first to discuss basic CFD analysis of mirror or kissing type in the DACA region.

Comparison of Treatment Options

The optimal treatment for incidental aneurysms remains controversial because clipping and coiling both come with pros and cons.¹ According to current data, all aneurysms should be treated in a single setting. The decision on single or staged treatment should be based on the location, morphology, and the rupture status of the aneurysm. Considering the reported articles, differentiation of the 2 modalities is limited and hard to perform. A larger series with a greater

number of cases is required for a comparison of mirror DACA treatment. Thenier-Villa et al.⁴⁹ found low shear area in the distal aneurysm after treatment of the proximal one. If the patient has an intracerebral hematoma with indication for urgent evacuation, then the same setting clipping for all aneurysms is a good option. With adequate preoperative imaging, a single burr-hole craniotomy for anterior interhemispheric was found to be an efficient approach for DACA unruptured aneurysm surgery.² Postponed emergency management of an unruptured mirror aneurysm could be an option in some cases but only with the risk assumption of a possible rupture, especially if the distal locations are included.

The difficulty in ascertaining which aneurysm caused the subarachnoid hemorrhage, dense adhesions, and increased tendency toward rupture should be considered carefully.²¹ Considering intracerebral hematoma and edema, a larger bone flap could be used. A one-stage treatment with a single general anesthesia and the same incision for both anterior interhemispheric and pterional approaches was found feasible and more comfortable. However, the decision on whether to make single or multiple aneurysm clippings should be made individually in accordance with the patient's state and surgeon preferences. The reviewed articles stated that clipping was performed on 20 patients.^{1,13,17-32} However, surgery carries the risk of different complications

in 28.57% of patients. Among all of the patients referred to in the articles, 2 lethal outcomes were reported.

Whether those DACA aneurysms were the kissing or mirror type seemed to be confusing. If described as a mirror and kissing, then they present 2 aneurysms adjacent to each other originating from 2 contralateral arteries with connected domes. Furthermore, kissing aneurysms can be classified in 2 different types.³⁵ Both terms are appropriate in the case we presented because the domes were in contact. However, precise differentiation is important, especially if there is a hematoma and edema to deal with during surgery. DACA aneurysms were found to be more prone to premature rupture.⁴⁰ During surgery, we found dissection of the attached domes in the kissing manner quite difficult, with the risk of bleeding in an already narrow space. In a mirror type, dissection should be easier from the medial side compared with the kissing group. Future classification in the DACA region should be proposed to decrease preoperative dilemma.

In general, embolization of DACA aneurysms is very difficult. Enesi et al.²⁴ reported the successful endovascular treatment of 2 cases. However, smaller neck, dome sizes, and an absence of intracerebral hematoma in the CT scan could influence the decision regarding final treatment. Another study reported a recurrence of previously coiled bilateral DACA aneurysms,^{25,50} which had to be treated through surgery. Otani et al.³¹

Table 2. Demographic Data and Patient Presentation: Aneurysm Characteristics and Management

Study	Sex	Age, years	MH	BLD	SAH	HEM	AP	Size	TM	CPC	MRT	AMA	LMA	SSS	CFD
Gupta et al., 2018 ³	F	55	Factor VII deficiency	+	+	+	DACA	N/A	Nonoperated	-	+	+	Basilar top, ACoA, PCoA bilateral; MCA bilateral; distal MCA bilateral	-	-
Mori et al., 1995 ¹⁶	F	43	N/A	+	+	-	Callosomarginal—pericallosal artery bifurcation	N/A	Clipping	-	-	-	-	N/A	-
Sousa et al., 2002 ¹⁷	F	65	Two strokes; family history of SAH in the daughter	+	-	+	Pericallosal and callosomarginal artery bifurcation	N/A	Clipping	-	-	+	Left posterior communicating artery	N/A	-
	F	55	N/A	+	+	+	Pericallosal artery	N/A	Clipping	+	+	-	-	N/A	-
Singh et al., 2018 ¹⁸	M	45	Severe headache with loss of consciousness	+	-	+	DACA at the junction pericallosal—callosomarginal arteries	Right 8.1 × 8.7, mm, neck 2.5 mm, left 9.2 × 6.5 mm, neck 3.5 mm.	Clipping	+	-	-	-	N/A	-
Fu et al., 2018 ¹⁹	F	54	Hypertension	+	+	-	Junction pericallosal—callosomarginal arteries	2 × 2 mm with wide neck.	Clipping	-	-	-	-	N/A	-
Dinc et al., 2006 ²⁰	F	52	N/A	+	+	-	Pericallosal arteries	N/A	Left clipped Right observed due to adherence to the cingulate gyrus and luminal thrombosis	-	-	+	Two right MCAs	+	-
Choi et al., 2011 ²¹	M	59	N/A	+	+	-	DACA	N/A	Clipping	-	-	-	-	N/A	-
Mizunari et al., 2011 ²²	M	62	N/A	+	+	+	DACA	N/A	Clipping	+	-	-	-	N/A	-
Nijjima et al., 1989 ²³	F	47	N/A	N/A	N/A	N/A	DACA pericallosal	N/A	Clipping	-	-	-	-	N/A	-
Enesi et al., 2013 ²⁴	M	48	N/A	+	+	-	DACA pericallosal	Right 4 × 3 mm, neck 2.5 mm, left 6 × 5 mm, neck 2 mm	Coil embolization	-	-	-	-	N/A	-
	F	40	N/A	+	-	+	Pericallosal—callosomarginal artery	Right 6 × 3 mm, neck 2.5 mm, left 3 × 2 mm, neck 2 mm.	Coil embolization	-	-	-	-	N/A	-

MH, medical history; BLD, bleeding; SAH, subarachnoid hemorrhage; HEM, hematoma; AP, aneurysm position; TM, treatment modality; CPC, complication; MRT, mortality; AMA, associated multiple aneurysm; LMA, location of multiple aneurysm; SSS, single-stage surgery; CFD, computational fluid dynamics; F, female; DACA, distal anterior cerebral artery; N/A, not available; ACoA, Anterior communicating artery; PCoA, posterior communicating artery; MCA, middle cerebral artery, M, male.

Continues

Table 2. Continued

Study	Age, Sex years	MH	BLD	SAH	HEM	AP	Size	TM	CPC	MRT	AMA	LMA	SSS	CFD
Wang et al., 2017 ²⁵	M 38	Regrowth of previously coiled aneurysms	–	–	–	Left A2	3.5 mm × 2.5 mm	Clipping	N/A	–	+	MCA	N/A	–
Yaşargil and Carter, 1974 ¹¹	M 44	SAH endocarditis (current)	+	+	–	Pericallosal –callosomarginal artery junction	N/A	Clipping	–	–	+	N/A	N/A	–
	M 53	Hypertension	+	+	–	Callosomarginal artery	N/A	Clipping	–	–	–	–	N/A	–
Wisoff and Flamm, 1987 ²⁶	M 60	SAH	+	+	+	DACA	N/A	Clipping	+	–	+	Left ophthalmic artery	–	–
	M 55	N/A	+	+	–	DACA	N/A	Clipping	–	–	+	Left PComA	+	–
Laitinen et al., 1960 ²⁷	M 45	SAH	+	+	–	Pericallosal artery	N/A	Right aneurysm ligated; observation of the left one.	–	–	+	Left MCA	–	–
	M 33	N/A	+	+	–	Pericallosal artery	N/A	Right aneurysm clipped, left ligated.	–	–	–	–	–	–
	M 27	Oxycephaly; operated for coarctation of the aorta SAH	+	+	–	Left pericallosal and right callosomarginal artery	N/A	Observation	–	–	–	–	–	–
Kawamata et al., 1999 ²⁸	F 67	Consciousness disturbance	+	–	+	Pericallosal artery at the bifurcation of the callosomarginal artery	N/A	Clipping	+	+	–	–	N/A	–
Kadoya et al., 1994 ²⁹	F 52	N/A	+	+	–	Bilateral pericallosal aneurysms	N/A	Clipping	–	–	+	Distal anterior cerebral arteries	–	–
Kuroiwa et al., 1992 ³⁰	F 57	Polycystic kidney and liver disease	+	+	–	Bilateral distal anterior cerebral artery and right MCA	N/A	Clipping	–	–	–	–	N/A	–
Otani N, et al., 2009 ³¹	F 72	N/A	+	+	–	Bilateral DACA, bilateral	N/A	Clipping	+	–	N/A	N/A	N/A	–
	F 68	N/A	+	+	–	Bilateral DACA	N/A	Clipping	–	–	N/A	N/A	N/A	–
	F 55	Hypertension, previous SAH	+	+	–	Bilateral DACA	N/A	Clipping	+	–	N/A	N/A	N/A	–
Alimohammadi et al. 2010 ³²	F 50	Speech disturbance, paraparesis	N/A	+	–	DACA	3–4 mm anterior and uplooking right DACA aneurysm	Clipping	N/A	–	–	–	+	–
Ahn et al., 2006 ³³	F 44	N/A	N/A	+	–	DACA	5 × 3 mm and 5 × 4 mm	Clipping	–	–	–	–	+	–
Megele et al., 1988 ³⁴	F 62	N/A	+	+	+	Pericallosal cerebral artery	N/A	Clipping	+	–	–	–	–	–

MH, medical history; BLD, bleeding; SAH, subarachnoid hemorrhage; HEM, hematoma; AP, aneurysm position; TM, treatment modality; CPC, complication; MRT, mortality; AMA, associated multiple aneurysm; LMA, location of multiple aneurysm; SSS, single-stage surgery; CFD, computational fluid dynamics; F, female; DACA, distal anterior cerebral artery; N/A, not available; ACoA, Anterior communicating artery; PComA, posterior communicating artery; MCA, middle cerebral artery, M, male.

reported a favorable outcome for endovascular treatment of 2 patients but of single DACA aneurysms that were poorly graded. Small sizes, fragility, the distal position, and complicated microcatheter navigation are some of the disadvantages of endovascular treatment.^{51,52} Cannulation of both carotid arteries is necessary^{16,17} but carries the risk of uncontrollable bleeding if the microcatheter is not in or near the bleeding site of the aneurysm.⁵³ According to our research, pipeline treatment of mirror DACA has yet to be applied.

CONCLUSIONS

In cases of ruptured mirror aneurysms followed by the presence of intracerebral hematoma, surgery is found to be the primary option with the best results. Precise imaging, diagnostics, and treatment are crucial for a positive outcome. Associated treatment of other multiple aneurysms has been found safe in a one-stage dual craniotomy procedure. According to our knowledge, this article presents the first CFD analysis of mirror DACA aneurysms associated with aneurysm multiplicity. At present, the size of the aneurysm, the hemodynamic influence, and the local configuration should all be considered during the preoperative assessment of multiple aneurysm cases.

REFERENCES

- International Study of Unruptured Intracranial Aneurysms Investigators. Unruptured intracranial aneurysms—risk of rupture and risks of surgical intervention. *N Engl J Med*. 1998;339:1725-1733.
- Choque-Velasquez J, Hernesniemi J. One burr-hole craniotomy: anterior interhemispheric approach in Helsinki neurosurgery. *Surg Neurol Int*. 2018;9:141.
- Gupta P, Sharma A, Singh J, Tanwar A. A rare case report of multiple intracranial aneurysms with factor VII deficiency. *Asian J Neurosurg*. 2018;13:814-816.
- Mehrotra A, Sharma P, Das KK, et al. Mirror aneurysms among multiple aneurysms: lesser of the two evils. *World Neurosurg*. 2016;92:126-132.
- Rinne J, Hernesniemi J, Niskanen M, Vapalahti M. Analysis of 561 patients with 690 middle cerebral artery aneurysms: anatomic and clinical features as correlated to management outcome. *Neurosurgery*. 1996;38:2-11.
- Inagawa T. Multiple intracranial aneurysms in elderly patients. *Acta Neurochir (Wien)*. 1996;106:119-126.
- Ostergaard JR, Hog E. Incidence of multiple intracranial aneurysms. Influence of arterial hypertension and gender. *J Neurosurg*. 1985;63:49-55.
- Qureshi AI, Suarez JJ, Parekh PD, et al. Risk factors for multiple intracranial aneurysms. *Neurosurgery*. 1998;43:22-26.
- Rinne J, Hernesniemi J, Puranen M, Saari T. Multiple intracranial aneurysms in a defined population: prospective angiographic and clinical study. *Neurosurgery*. 1994;35:803-808.
- Meissner I, Torner J, Huston J, et al. Mirror aneurysms: a reflection on natural history. *J Neurosurg*. 2012;116:1238-1241.
- Yaşargil MG, Carter LP. Saccular aneurysms of the distal anterior cerebral artery. *J Neurosurg*. 1974;40:218-223.
- Yaşargil MG. *Microneurosurgery*. In: *Clinical Considerations, Surgery of the Intracranial Aneurysms and Results (Microsurgical Anatomy of Basal Cisterns & Vessels of Brain)*. Vol. 2. New York, NY: Thieme; 1984:33-123.
- Komiyama M, Yasui T, Tamura K, Nagata Y, Fu Y, Yagura H. "Kissing aneurysms" of the internal carotid artery. *Neurol Med Chir (Tokyo)*. 1994;34:360-364.
- Sun Z, Wu C, Wang F, Xue Z, Xu B, Zhou D. Surgical management of intracranial mirror aneurysms. *Zhonghua Wai Ke Za Zhi*. 2013;51:912-915.
- Lehecka M, Dashti R, Lehto H, Kivisaari R, Niemelä M, Hernesniemi J. Distal anterior cerebral artery aneurysms. *Acta Neurochir Suppl*. 2010;107:15-26.
- Mori T, Fujimoto M, Shimada K, Shin H, Sakakibara T, Yamaki T. Kissing aneurysms of distal anterior cerebral arteries demonstrated by magnetic resonance angiography. *Surg Neurol*. 1995;43:497-499.
- Sousa J, Iyer V, Roberts G. "Mirror image" distal anterior cerebral artery aneurysms: a case report of two patients with review of literature. *Acta Neurochir (Wien)*. 2002;144:933-935.
- Singh S, Jain K, Jain V, Saroha A. Mirror image of bilateral DACA aneurysm with its successful surgical management. *Surg Neurol Int*. 2018;9:80.
- Fu C-Y, Chen J-L, Liu Z-H, Wang P-C, Duan C-Z, Zhao J-N. Kissing aneurysms of the distal anterior cerebral artery: a case report and literature review. *Exp Ther Med*. 2018;15:3471-3476.
- Dinc C, Iplikcioglu AC, Bikmaz K, Kosdere S, Navruz Y. Distal anterior cerebral artery mirror aneurysms and middle cerebral artery aneurysms. *Neurol Med Chir (Tokyo)*. 2006;46:438-440.
- Choi C-Y, Han S-R, Yee G-T, Lee C-H. Kissing aneurysms of the distal anterior cerebral artery. *J Clin Neurosci*. 2011;18:260-262.
- Mizunari T, Murai Y, Kobayashi S, Sakai N, Teramoto A. Long-lasting narrowing of the parent artery after bilateral clipping of mirror-image aneurysms of distal anterior cerebral arteries: a case report. *J Nippon Med Sch*. 2011;78:178-183.
- Niijima KH, Yonekawa Y, Kawano T. Bilateral pericallosal artery aneurysms in a mirror position. *No Shinkei Geka*. 1989;17:779-781 [in Japanese].
- Enesi E, Rroji A, Demneri M, Vreto G, Petrela M. Mirror image distal anterior cerebral artery aneurysms treated with coil embolization: a report of two cases and literature review. *Interu Neuroradiol*. 2013;19:49-55.
- Wang HW, Sun ZH, Wu C, Xue Z, Yu XG. Surgical management of recurrent aneurysms after coiling treatment. *Br J Neurosurg*. 2017;31:96-100.
- Wisoff JH, Flamm ES. Aneurysms of the distal anterior cerebral artery and associated vascular anomalies. *Neurosurgery*. 1987;20:735-741.
- Laitinen L, Snellman A. Aneurysms of the pericallosal artery: a study of 14 cases verified angiographically and treated mainly by direct surgical attack. *J Neurosurg*. 1960;17:447-458.
- Kawamata T, Suzuki Y, Matsumoto H, Ozawa H, Matsumoto K. Bilateral distal anterior cerebral artery aneurysm associated with supreme anterior cerebral artery: case report. *No Shinkei Geka*. 1999;27:341-346 [in Japanese].
- Kadoya C, Momota Y, Urasaki E, Wada S, Yokota A. Double bilateral symmetrical aneurysms—case report. *Neurol Med Chir (Tokyo)*. 1994;34:35-37.
- Kuroiwa T, Tanabe H, Takatsuka H, et al. Bilateral distal anterior cerebral artery aneurysms associated with polycystic kidney and liver disease; a case report. *No Shinkei Geka*. 1992;20:905-908 [in Japanese].
- Otani N, Takasato Y, Masaoka H, et al. Clinical features and surgical outcomes of ruptured distal anterior cerebral artery aneurysms in 20 consecutively managed patients. *J Clin Neurosci*. 2009;16:802-806.
- Alimohammadi M, Bidabadi MS, Amirjamshidi A. Bilateral "kissing" aneurysms of the distal pericallosal arteries report of a case and review of the literature. *Neurosurg Q*. 2010;20:308-310.
- Ahn HJ, Koh HS, Kim Y. Kissing aneurysms of distal anterior cerebral arteries. *J Korean Neurosurg Soc*. 2006;39:238-240.
- Megele R, Gruss P, Lehr H. A case of symmetrical pericallosal aneurysms with recurrent hemorrhage. *Neurochirurgia (Stuttg)*. 1988;31:154-156.
- Harada K, Orita T, Ueda Y. Large kissing aneurysms of the middle cerebral artery: a case report—classification of kissing aneurysms. *No Shinkei Geka*. 2004;32:513-517 [in Japanese].
- Andrews RJ. Intracranial aneurysms: characteristics of aneurysms in siblings. *N Engl J Med*. 1977;297:115.
- Weil SM, Olivi A, Greiner AL, Tobler WD. Multiple intracranial aneurysms in identical twins. *Neurochir (Wien)*. 1988;95:121-125.

38. Yamada K, Nakahara T, Kishida K, Yano T, Yamamoto K, Ushio Y. Multiple "mirror" aneurysms involving intracavernous carotid arteries and vertebral arteries: case report. *Surg Neurol*. 2000;54:361-365.
39. Baccin CE, Krings T, Alvarez H, Ozanne A, Lasjaunias P. Multiple mirror-like intracranial aneurysms. Report of a case and review of the literature. *Acta Neurochir (Wien)*. 2006;148:1091-1095.
40. Casimiro MV, McEvoy AW, Watkins LD, Kitchen ND. A comparison of risk factors in the etiology of mirror and nonmirror multiple intracranial aneurysms. *Surg Neurol*. 2004;61:541-545.
41. Grochowski C, Litak J, Kulesza B, et al. Size and location correlations with higher rupture risk of intracranial aneurysms. *J Clin Neurosci*. 2018;48:181-184.
42. Huang Z-Q, Zhou X-W, Hou Z-J, et al. Risk factors analysis of mirror aneurysms: a multi-center retrospective study based on clinical and demographic profile of patients. *Eur J Radiol*. 2017;96:80-84.
43. Kozyrev D, Jahromi B, Thiarawat P, et al. Three distal anterior cerebral artery aneurysms in the same branch associated with five additional intracranial aneurysms. *Surg Neurol Int*. 2017;8:62.
44. Giordan E, Sorenson TJ, Brinjikji W, Vine R, Lanzino G. Risk factors for growth of conservatively managed unruptured intracranial aneurysms. *Acta Neurochir (Wien)*. 2018;160:2419-2423.
45. Zhang Y, Yang X, Wang Y, et al. Influence of morphology and hemodynamic factors on rupture of multiple intracranial aneurysms: matched-pairs of ruptured-unruptured aneurysms located unilaterally on the anterior circulation. *BMC Neurol*. 2014;14:253.
46. Doddasomayajula R, Chung BJ, Mut F, et al. Hemodynamic characteristics of ruptured and unruptured multiple aneurysms at mirror and ipsilateral locations. *AJNR Am J Neuroradiol*. 2017;38:2301-2307.
47. Tian Z, Zhang Y, Jing L, Liu J, Zhang Y, Yang X. Rupture risk assessment for mirror aneurysms with different outcomes in the same patient. *Front Neurol*. 2016;7:219.
48. Meng H, Tutino VM, Xiang J, Siddiqui A. High WSS or low WSS? Complex interactions of hemodynamics with intracranial aneurysm initiation, growth, and rupture: toward a unifying hypothesis. *AJNR Am J Neuroradiol*. 2014;35:1254-1262.
49. Thenier-Villa JL, Riveiro Rodríguez A, Martínez-Rolán RM, et al. Hemodynamic changes in the treatment of multiple intracranial aneurysms: a computational fluid dynamics study. *World Neurosurg*. 2018;118:e631-e638.
50. Wang WX, Xue Z, Li L, et al. Treatment strategies for intracranial mirror aneurysms. *World Neurosurg*. 2017;100:450-458.
51. Keston P, White PM, Horribine L, Sellar R. The endovascular management of pericallosal artery aneurysms. *J Neuroradiol*. 2004;31:384-390.
52. Liu J, Huang Q, Shen J, Xu Y. Endovascular treatment of ruptured distal anterior cerebral artery aneurysm. *Neurol India*. 2010;58:259.
53. Matsumoto H, Takechi A, Kohno K, Sasaki U. "Kissing aneurysms" of the anterior communicating artery treated with coil embolization. *J Endovasc Ther*. 2005;12:750-754.

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