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Microsurgical Treatment of 86 Anterior Choroidal Artery Aneurysms: Analysis of Factors Influencing the Prognosis

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Abstract

Purpose To explore factors affecting the prognosis of choroidal anterior artery aneurysm (AChAA) and provide a reference for improving the postoperative outcome.

Methods The clinical data of 86 patients with AChAA who underwent treatment by a single surgeon were collected and analyzed retrospectively. Univariate analysis and multivariate logistic regression analysis were conducted to examine 12 factors that possibly affected outcome.

Results The five factors that affected the patient outcomes were times of subarachnoid hemorrhage (SAH), characteristics of SAH on computed tomography (CT), Hunt-Hess grade, aneurysm size, and presence or absence of postoperative complications. Characteristics of SAH on CT (odds ratio [OR]: 3.727; $p = 0.000$; 95% confidence interval [CI], 1.850–7.508), aneurysm size (OR: 6.335; $p = 0.000$; 95% CI, 2.564–15.647), and presence or absence of postoperative complications (OR: 4.141; $p = 0.000$; 95% CI, 1.995–8.599) were independent risk factors influencing the prognosis. In addition, the incidence of postoperative ischemia (caused by anterior choroidal artery syndrome) is related to the aneurysm emitting part and presence or absence of intraoperative rupture.

Conclusions The analysis of characteristics of SAH on CT, aneurysm size, and presence or absence of postoperative complications can roughly determine the outcome of patients with AChAAs.

Keywords
- ► anterior choroidal artery aneurysm
- ► prognosis
- ► risk factors

Introduction

An anterior choroidal artery aneurysm (AChAA) originates from the origin of the choroidal artery, accounting for 2 to 5% of all intracranial aneurysms.[1,2] The anterior choroidal artery (AChA) provides a blood supply to an extremely important region of the brain.[3] When the AChAA is clipped, the AChA and its perforating branch may be narrowed or occluded, resulting in ischemia and infarction in the blood supply area, and leading to choroidal artery syndrome. This syndrome presents with contralateral hemiplegia (often involving face, arm, and leg), dysarthria, lethargy, and occasional sensory and vision loss.[4–6]

Many factors influence the prognosis of patients with AChAA. This article retrospectively analyzes the clinical data of 2,095 patients with intracranial aneurysms from December 1997 to December 2018 in the Department of Neurosurgery, Affiliated Hospital of Qingdao University, 86 of whom had AChAAs accounting for 4.1%. Logistical multiple regression analysis was used to assess the surgical risk accurately, and to develop appropriate treatment plans to improve the postoperative outcome.

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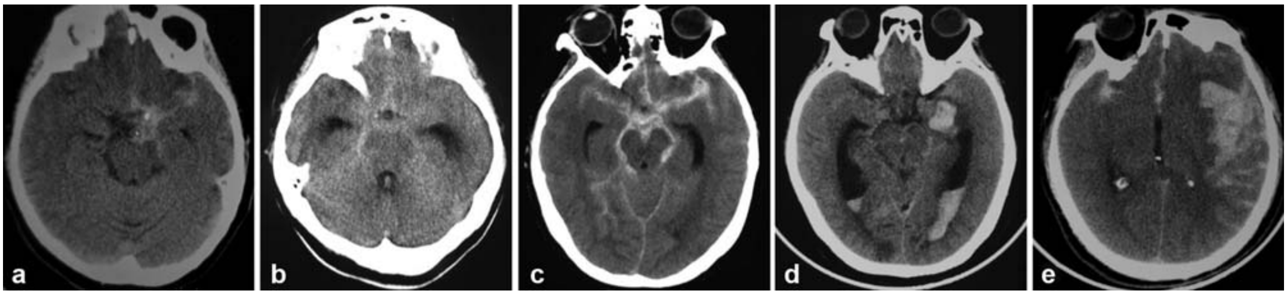

Fig. 1 Axial computed tomography scans showing the different degrees of subarachnoid hemorrhage (SAH)caused by rupture of an anterior choroidal artery aneurysm. (**a**) Type 1: SAH confined to the ipsilateral crural cistern. (**b**) Type 2: small amount of blood clot in the bilateral Sylvian cistern and suprasellar cistern. (**c**) Type 3: moderate blood clot in the bilateral Sylvian cistern and suprasellar cistern. (**d**) Type 4: more than a moderate blood clot in the bilateral Sylvian cistern and suprasellar cistern, accompanied by intraventricular hemorrhage. (**e**) Type 5: ipsilateral temporal pole hematoma.

Material and Methods

Imaging Examination

A total of 85 of 86 patients (one without computed tomography [CT] examination: only lumbar puncture test positive) had CT performed within 48 hours after symptom onset. A classification of the CT features of SAH was used: type 1: SAH confined to the ipsilateral crural cistern (►**Fig. 1a**); type 2: small amount of hematoma in the bilateral sylvian cistern and suprasellar cistern (►**Fig. 1b**); type 3: moderate hematoma in the bilateral sylvian cistern and suprasellar cistern (►**Fig. 1c**); type 4: more than a moderate amount of hematoma in the bilateral sylvian cistern and suprasellar cistern, accompanied by intraventricular hemorrhage (►**Fig. 1d**); and type 5: ipsilateral temporal pole hematoma (►**Fig. 1e**). Seven patients showed no SAH, referred to as type 0. Digital subtraction angiography (DSA) or computed tomography angiography (CTA) examination confirmed an AChAA.

Treatment Methods

Overall, we used the pterional approach for 86 cases of AChAAs. If the patient's condition was severe before surgery Hunt-Hess grade IV, or with intracranial hematoma then a modified pterional approach and decompressive craniectomy was applied. During the operation, the hematoma in each cerebral cistern was removed as much as possible, and a papaverine wet cottonoid was applied. Postoperatively, nimodipine and antibiotics were given if needed.

Selection and Criteria of Variables

This study selected 12 indicators that may affect the prognosis of AChAAs. (1) Age was divided into < 20 years, 20 to 39 years, 40 to 59 years, and > 60 years (there were no patients < 20 years of age); (2) sex; (3) times of subarachnoid hemorrhage (SAH); (4) characteristics of SAH on CT; (5) Hunt-Hess grade; (6) aneurysm side; (7) aneurysm size; (8) aneurysm emitting site (►**Fig. 2**); (9) aneurysm dome projection (►**Fig. 3**); (10) timing of surgery divided into early (< 3 days), medium (3–14 days), and late (> 14 days); (11) presence or absence of intraoperative rupture; and (12) presence or absence of complications.

Outcome Criteria

The outcome of 86 patients was evaluated at the time of discharge (2–4 weeks after surgery). The assessment criteria were based on the modified Rankin Scale (mRS). To facilitate the statistics, an mRS grade of 0 to 2 was determined representing a good outcome, and grade 3 to 6 was determined representing to have a poor prognosis.

Statistical Analysis

Statistical analysis was performed using SPSS, v.19.0 (IBM Corp., Armonk, New York, United States) software. Twelve indicators as described earlier were used as independent variables. The prognostic efficacy was used as the dependent variable. One-way rank sum test analysis and multivariate logistic stepwise regression analysis were used. A $p < 0.05$ was

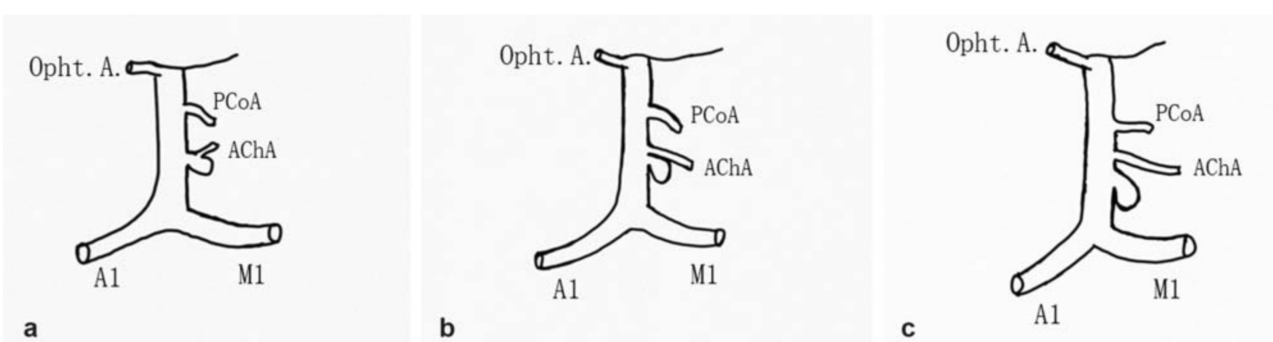

Fig. 2 Aneurysms are divided into three types according to the location of the origin. (**a**) Type I: Aneurysm is emitting from the beginning of the anterior choroidal artery (AChA). (**b**) Type II: Aneurysm is emitting from the posterior wall of the corner between the AChA and internal carotid artery. (**c**) Type III: The aneurysm is emitting from the wall of the first AChA segment. Opht. A, ophthalmic artery; PCoA. posterior communicating artery.

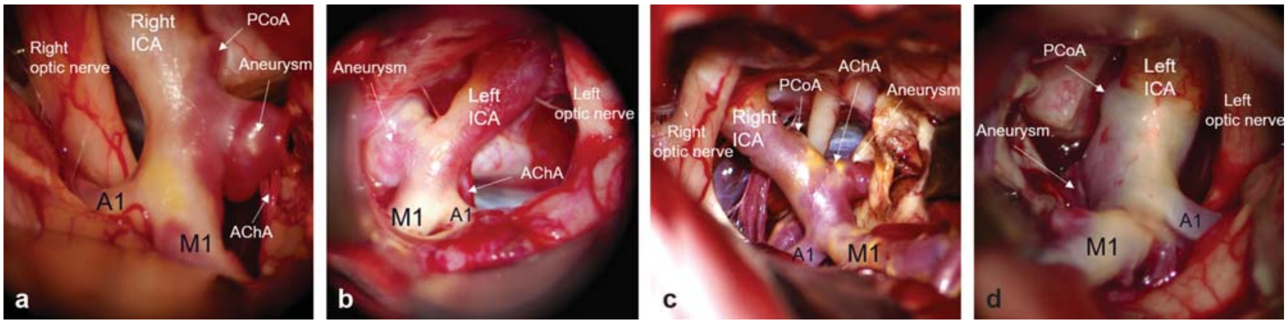

Fig. 3 The aneurysm is divided into four types according to the dome projection. (**a**) Type I: Upper lateral dome projection. (**b**) Type II: Lower lateral dome projection. (**c**) Type III: Upper posterior dome projection, with the deome embedded in the pole of the temporal lobe. (**d**) Type IV: Lower posterior dome projection. A1, anterior cerebral artery; AChA, choroidal artery; ICA, internal carotid artery; M1, middle cerebral artery; PCoA, posterior communicating artery.

considered statistically significant. Risk factors associated with prognosis in patients with AChAAs were identified.

Results

Clinical Data

There were 111 aneurysms in 86 patients including 86 AChAs and 25 aneurysms in other sites. The 37 men and 49 women were not younger than 20 years of age, 7 cases were 20 to 39 years old, 54 cases 40 to 60 years old, and 25 cases 60 years or older. There were 7 patients without preoperative aneurysm rupture, 73 with a single rupture, 1 with 2 ruptures, and 5 with 3 ruptures. Hunt-Hess grade distribution was 0: 7 cases; grade I: 5 cases; grade II: 45 cases; grade III: 22 cases; grade IV: 2 cases; and grade V: 5 cases. The CT features of SAH were divided into six types: type 1 had a total of 35 cases (41.2%); type 2, 20 cases (23.5%); type 3, 17 cases (20%); type 4, 2 cases (2.4%); and type 5, 4 cases (4.7%). Seven patients (8.2%) showed no SAH, referred to as type 0 (►**Table 1**).

Surgery

There were 111 aneurysms in 86 patients including one blister aneurysm wrapped with a clip-reinforced muslin sling. All 111 aneurysms were successfully clipped. There were 13 patients with complications after the operation: 6 with cerebral infarction, 3 with cerebral hemorrhage (one case with sudden postoperative respiratory arrest 3 days later, 1 with sudden basal ganglia hemorrhage, and 1 case with postoperative contralateral cerebral hemorrhage), 2 with hydrocephalus, and 2 cases with cerebral edema. In 80 of the 86 patients (93.02%) a good result was obtained. Six patients (6.98%) had a postoperative ischemic stroke. The operative mortality rate was 5.81%.

Table 1 Single-factor rank sum test results ($n = 86$)

Variable	Healing	Self-care	Vegetative state	Death	*N*	*p* Value
Age, y						0.908
< 20	0	0	0	0	0	
20–39	6	1	0	0	7	
40–59	49	0	1	4	54	
> 60	23	1	0	1	25	
Sex						0.762
Male	34	0	1	2	37	
Female	44	2	0	3	49	
Times of SAH						0.000
0	7	0	0	0	7	
1	70	2	1	0	73	
2	1	0	0	0	1	
3	0	0	0	5	5	
Characteristics of SAH on CT						0.000
Type 0	7	0	0	0	7	
Type 1	34	1	0	0	35	
Type 2	20	0	0	0	20	
Type 3	15	1	1	0	17	

(*Continued*)

Table 1 (*Continued*)

Variable	Healing	Self-care	Vegetative state	Death	*N*	*p* Value
Type 4	0	0	0	2	2	
Type 5	1	0	0	3	4	
Hunt-Hess grade						0.000
0	7	0	0	0	7	
I	5	0	0	0	5	
II	43	2	0	0	45	
III	22	0	0	0	22	
IV	0	0	1	1	2	
V	1	0	0	4	5	
Aneurysm side						0.369
Left	46	1	0	3	49	
Right	23	1	1	2	37	
Size, mm						0.000
<5	39	2	0	0	41	
5–10	37	0	0	0	37	
10–25	1	0	0	2	3	
>25	1	0	1	3	5	
Emitting site						0.323
Type I	6	0	1	1	8	
Type II	68	2	1	4	75	
Type III	3	0	0	0	3	
Orientation						0.898
Upper lateral	6	0	0	1	7	
Lower lateral	27	1	0	1	29	
Upper posterior	22	0	0	2	24	
Lower posterior	23	1	1	1	26	
Timing of surgery, d						0.076
<3	46	2	1	5	54	
3–14	21	0	0	0	21	
>14	11	0	0	0	11	
Intraoperative situation						0.707
Aneurysm rupture	7	1	1	5	79	
Nonrupture	72	1	0	0	7	
Complication:						0.000
No	73	0	0	0	73	
With complications	5	2	1	5	13	

Abbreviations: CT, computed tomography; SAH, subarachnoid hemorrhage.
The times of SAH, Hunt-Hess grade, the CT features of SAH, aneurysm's size and postoperative complications were statistically significant ($p < 0.05$).

Follow-up Results

A total of 86 patients were assessed by mRS at discharge (2–4 weeks after surgery): 78 patients (90.7%) at grade 0 to 1, 2 patients (2.3%) at grade 2 to 3, and 1 patient at grade 4 to 5 (accounting for 1.2%); 5 cases at grade 6 (accounting for 5.8%). Overall, 67 patients underwent DSA or CTA reexamination within 1 month after surgery, showing no residual or recurrent aneurysm. Patients were followed up for half a year, and 19 patients were found to have aneurysms at other sites. The remaining patients did not undergo regular CTA or DSA examination at the time of discharge, and most of them were lost to follow-up.

Statistical Results

The results of the statistically ordered categorical rank sum test of 12 indicators showed that SAH times ($p = 0.000$),

Table 2 Logistic multivariate regression analysis of 86 patients with anterior choroidal artery aneurysm

Variable	*B*	SE	*Wald*	OR value	95% CI	*p* Value
CT features of SAH	1.316	0.357	13.589	3.727	1.850–7.508	0.000
Aneurysm size	1.846	0.461	16.035	6.335	2.564–15.647	0.000
Complications or not	1.421	0.373	14.513	4.141	1.995–8.599	0.000
Hunt-Hess grade	0.947	0.297	10.167	2.578	1.441–4.612	0.001
Times of SAH	2.004	0.908	4.871	7.418	1.251–43.992	0.027

Abbreviations: B, regression coefficient; CI, confidence interval; CT, computed tomography; OR, odds ratio; SAH, subarachnoid hemorrhage; SE, standard error; Wald, testing static.

Hunt-Hess grade ($p = 0.000$), characteristics of SAH on CT ($p = 0.000$), aneurysm size ($p = 0.000$), and presence or absence of postoperative complications ($p = 0.000$) were statistically significant. There were no significant differences in other factors such as age, sex, aneurysm side, emitting site, dome projection, timing of surgery, and presence or absence of intraoperative rupture ($p > 0.05$) (►**Table 1**).

Logistic multivariate regression analysis was performed using the five factors related to outcome as independent variables and mRS grading as the dependent variable. The results showed that the prognostic differences of the five indicators were statistically significant ($p < 0.05$). Among them, there is a higher correlation between characteristics of SAH on CT, aneurysm size, and presence or absence of complications, whereas SAH times and the Hunt-Hess grade were less relevant (►**Table 2**).

Regarding ischemic complications (AChA syndrome), according to the chi-square test or Fisher exact test, we found that characteristics of SAH on CT ($p = 0.074$), presence or absence of preoperative SAH ($p = 0.073$), Hunt-Hess classification ($p = 0.186$), and aneurysm size ($p = 1.000$) were not significantly associated with postoperative AChA syndrome. However, aneurysm emitting site ($p = 0.000$) and the presence or absence of intraoperative rupture ($p = 0.000$) seem to have affected the results. The anatomy of the AChA adjacent to or incorporated into the neck of the aneurysm (►**Fig. 2a**) made the clipping more difficult than the other groups (►**Fig. 2b,c**) and less likely to maintain patency of the AChA (►**Table 3**).

Discussion

The special feature of the AChAA is the AChA that has many bends, a long course, and a thin diameter. The beginning of the AChA is often a single trunk, and its end branch (anterior perforating artery) the posterior limb of the internal capsule lacks collateral circulation.[1,7–11] When the terminal segment is occluded, infarction in the supplying territory can occur, clinically characterized by AChA syndrome (►**Fig. 4**). The incidence of persistent AChA syndrome (duration > 7 days) is ~ 5.3 to 15.7%.[4–6,12] Therefore, AChAAs have special characteristics compared with other aneurysms.[4,7,8,13,14] In particular, attention should be paid to the study of factors influencing the outcome of the AChAA.

In earlier studies, although some factors affecting the outcome of surgery were reported, most of them are the records of aneurysms in various areas and of different surgeons. Therefore, factors such as surgical techniques of different surgeons and proficiency dealing with different sites of aneurysms will affect the results of these studies. This study collected and retrospectively analyzed the clinical data of 86 patients with AChAAs operated by a single surgeon from December 1997 to December 2018. Analysis of relevant factors affecting outcome will help assess the risk of surgery and develop targeted treatment programs to improve the results of surgery. Our study showed that patient age, sex, aneurysm side, emitting part, dome projection, timing of surgery, and presence or absence of intraoperative rupture have little effect on postoperative outcomes. Times of SAH, Hunt-Hess grade, characteristics of SAH on CT, the size of aneurysm, and presence or absence of postoperative complications were the relevant factors affecting postoperative outcomes. Among these, aneurysm size, characteristics of SAH on CT, and presence or absence of postoperative complications are independent risk factors and are discussed in detail.

The SAH caused by the AChAA is mostly located deeply in the proximal ipsilateral Sylvian cistern. This distribution of SAH is different from other aneurysm sides.

The preoperative CT helps determine the location and the severity of bleeding. I It also helps determine the size of the bone flap and whether to perform a decompressive craniectomy. In high-grade SAH with intracerebral hematoma, we should consider an extented pterional approach. For patients with intraventricular or temporal lobe hematoma, the lateral ventricle puncture can be used to reduce intracranial pressure. The CT features of SAH are related to outcome, but do not allow to predict the site of the aneurysm.

Aneurysm size is an independent factor affecting outcome. In this group of 86 cases of AChAAs, there were 38 aneurysms < 5 mm, accounting for 44.2%. According to our previous study, AChAAs were smaller than the PCoA aneurysm. The smaller the aneurysm, the more difficult it is to clip. If the aneurysm is too small or its wall too thin, a thin layer of cotton fiber can be wrapped around the neck (►**Fig. 5**) before clipping with a mini-clip. Postoperative ischemia and severe complications such as cerebral hemorrhage, hydrocephalus, and cerebral edema are independent factors affecting outcome. Among them, the AChA syndrome is one of the most serious complications of ACHAA clipping. The aneurysm emitting site and the presence or absence of

Table 3 Analysis of ischemic complications (caused by anterior choroidal artery syndrome) after surgical clipping of anterior choroidal artery aneurysm

Variable	No. of all patients ($n=86$)	AChA infarction	No AChA infarction	Incidence rate, %	*p* Value
Characteristics of SAH on CT					0.074
Group 1 (0, type 1, 2)	62	2	60	3.2	
Group 2 (type 3, 4, 5)	23	4	19	17.4	
Preoperative SAH					0.073
No SAH	7	2	5	28.6	
SAH	79	4	75	5.1	
Hunt-Hess grade					0.186
Group 1 (0, I, II)	57	2	55	3.5	
Group 2 (III, IV, V)	29	4	25	13.8	
Size, mm					1.000
< 5	41	3	38	7.3	
> 5	45	3	42	6.7	
Intraoperative situation					0.000
Nonrupture	72	5	2	71.4	
Aneurysm rupture	7	1	78	1.3	
Aneurysm emitting site					0.000
Group 1 (type I)	8	5	3	62.5	
Group 2 (type II, III)	78	1	77	1.3	

Abbreviations: AChA, anterior choroidal artery; CT, computed tomography; SAH, subarachnoid hemorrhage.

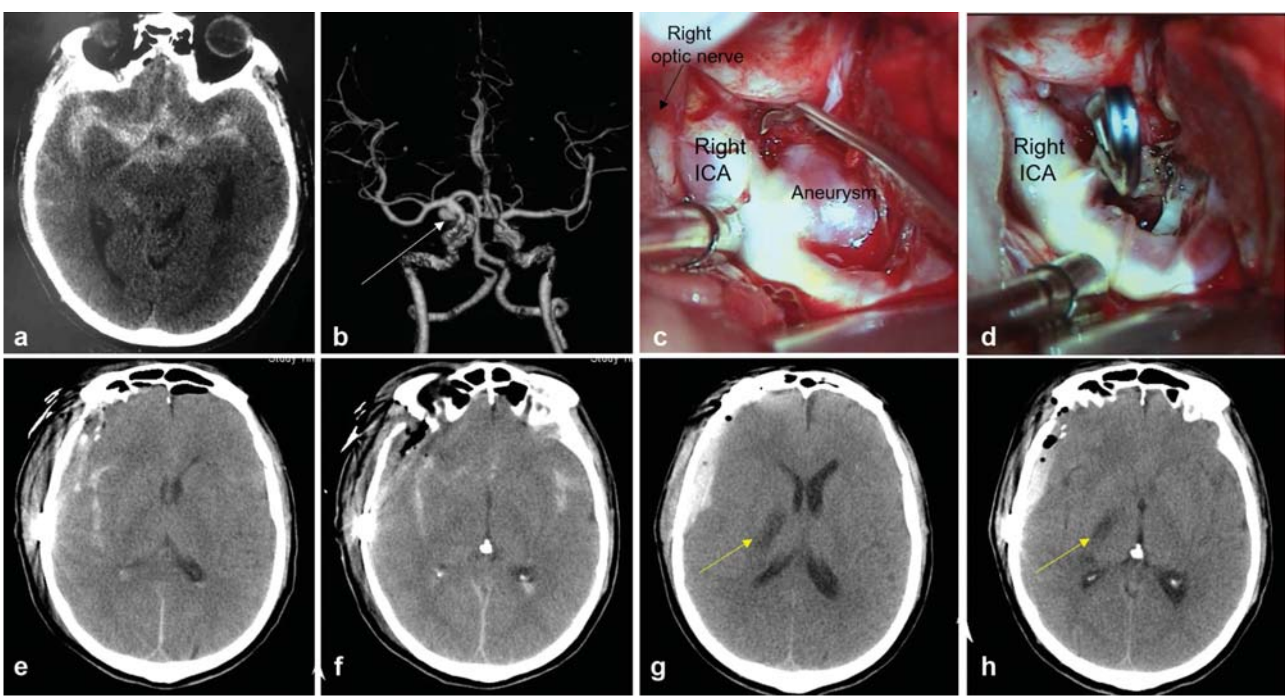

Fig. 4 A 69-year-old male patient. Preoperative diagnosis is right choroidal artery aneurysm. (**a**) Preoperative computed tomography (CT) showed subarachnoid hemorrhage. (**b**) Preoperative computed tomography angiography showed choroidal artery aneurysm. (**c**) Aneurysm. (**d**) The aneurysm was clipped. (**e, f**) CT on the first day after surgery. (**g, h**) On day 10 after surgery, the CT shows a right basal ganglia infarction indicative of a anterior choroidal artery syndrome (arrows). ICA, internal carotid artery.

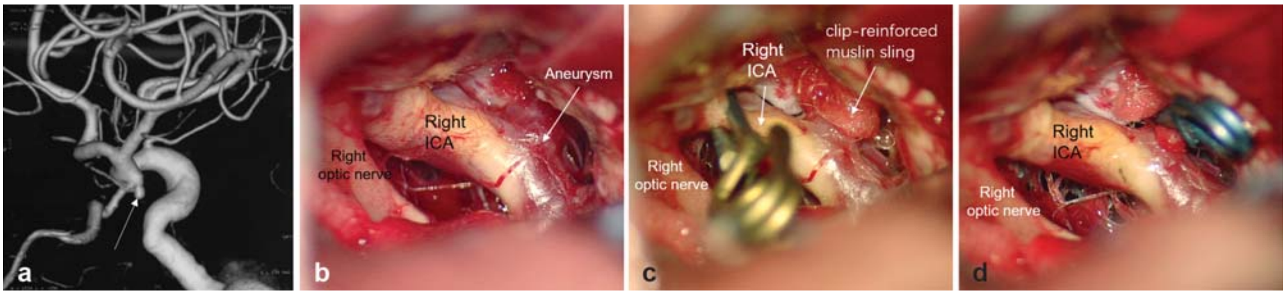

Fig. 5 One case of a blister aneurysm wrapped with a clip-reinforced muslin sling. (**a**) Preoperative computed tomography angiography suggesting anterior choroidal artery aneurysm. (**b**) Before aneurysm clipping. (**c**) Muslin sling wrapped around the aneurysm neck before clipping. (**d**) The muslin sling wrapped around the neck of the aneurysm. ICA, internal carotid artery.

intraoperative rupture of the aneurysm are associated with a higher incidence of the AChA syndrome. Causes of the AChA syndrome after surgery mainly include excessive turbulence of blood vessels during surgery, thromboembolism of the AChA and its branches, edema, clip displacement, vasospasm, and reduction of the collateral blood supply.[12,15–18]

In recent years, many authors have used a variety of methods for detection of accidental AChA obliteration by the clip: intraoperative angiography, muscle motor evoked potentials monitoring[19]; and intraoperative micro Doppler sonography.

Conclusions

In summary, the study indicates that the times of SAH, Hunt-Hess grade, aneurysm size, characteristics of SAH on CT, and the presence or absence of postoperative complications are the relevant risk factors for postoperative outcomes. Aneurysm size, characteristics of SAH on CT, and presence or absence of postoperative complications are independent risk factors of outcome. In addition, we found that the incidence of postoperative ischemia is related to the aneurysm emitting part and presence or absence of intraoperative rupture. By analyzing these factors, the outcome of patients with AChAA can be roughly determined

Conflict of Interest
None declared.

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