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Microsurgical Treatment of Anterior Communicating Artery Aneurysms: An Analysis of 74 Consecutive Cases. Approach Side Choice and Outcome Considerations

Tratamento microcirúrgico de aneurismas da artéria comunicante anterior: Uma análise de 74 casos consecutivos. Escolha da abordagem e considerações sobre resultados

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Abstract

Introduction Anterior communicating artery aneurysms (ACoAAs) are intracranial aneurysms whose treatment is still considered a challenging task.

Materials and Methods Altogether, 74 patients were included in this study. The variables included age, sex, comorbidities, incidence of subarachnoid hemorrhage (SAH), the Fisher, Hunt-Hess, and WFNS scores, approach side, length of hospital stay, and mortality. We also investigate A1/A2 dimensions, association with approach side choice and the influence of surgeon's experience on the outcome.

Results There were 61 patients (82.2%) admitted with SAH and 13 were treated for unruptured aneurysms. The A1 and A2 branches were larger ipsilaterally to the selected approach side ($p < 0{,}001$). No deaths occurred in the unruptured aneurysm group. In the SAH group, mortality was strongly correlated with the Hunt-Hess score ($p < 0.001$), Fisher grade ($p < 0.001$), and WFNS score ($p < 0.001$). No significant difference was found in mortality between the right-side and the left-side approaches ($p = 0.253$). A significant survival difference was identified on the group operated by the senior surgeon versus the non-senior group ($p = 0.048$).

Keywords
- vascular neurosurgery
- anterior communicating artery aneurysm
- subarachnoid hemorrhage
- microsurgery

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Discussion and Conclusion A1 dominance was identified as a factor associated to the approach side for SAH cases at our center. Understanding the factors involved in brain aneurysm surgery remains a relevant and underexplored subject. Further studies involving larger case series and multicenter collaborations are necessary to elucidate these factors and to determine the external validity of our findings.

Resumo

Introdução Os aneurismas da artéria comunicante anterior (ACoAA) são aneurismas intracranianos cujo tratamento ainda é considerado uma tarefa desafiadora.

Materiais e Métodos Ao todo, 74 pacientes foram incluídos neste estudo. As variáveis incluíram idade, sexo, comorbidades, incidência de hemorragia subaracnóidea (HAS), escala de Fisher, Hunt-Hess e WFNS, lado de abordagem, tempo de internação e mortalidade. Também investigamos as dimensões A1/A2, a associação com a escolha do lado de abordagem e a influência da experiência do cirurgião no resultado.

Resultados Foram admitidos 61 pacientes (82,2%) com HAS e 13 foram tratados por aneurismas não rotos. Os ramos A1 e A2 foram maiores ipsilateralmente ao lado de abordagem selecionada ($p < 0{,}001$). Nenhuma morte ocorreu no grupo de aneurismas não rotos. No grupo HAS, a mortalidade esteve fortemente correlacionada com a escala de Hunt-Hess ($p < 0{,}001$), pontuação de Fisher ($p < 0{,}001$) e pontuação WFNS ($p < 0{,}001$). Não foi encontrada diferença significativa na mortalidade entre as abordagens direita e esquerda ($p = 0{,}253$). Foi identificada diferença significativa de sobrevida no grupo operado pelo cirurgião sênior versus o grupo não sênior ($p = 0{,}048$).

Discussão e Conclusão A dominância A1 foi identificada como fator associado ao lado de abordagem dos casos de HAS em nosso centro. A compreensão dos fatores envolvidos na cirurgia de aneurisma cerebral permanece um assunto relevante e pouco explorado. Mais estudos envolvendo séries de casos maiores e colaborações multicêntricas são necessários para elucidar esses fatores e para determinar a validade externa de nossas descobertas.

Palavras-chave
- neurocirurgia vascular
- aneurisma da artéria comunicante anterior
- hemorragia subaracnoídea
- microcirurgia

Introduction

Anterior communicating artery aneurysms (ACoAAs) are among the most frequent intracranial aneurysms in several case series, and their treatment is still considered a challenging task.[1,2] Even for non-ruptured aneurysms, technical difficulties may be associated with morbidity. In cases presenting with subarachnoid hemorrhage (SAH), the degree of bleeding and clinical status of the patient are frequently associated, and both have implications for the outcome.[3]

Another variable for the treatment of ACoAAs is selecting the approach side. Some authors have recommended the systematic use of right-side approaches, as most surgeons are right-handed and the left hemisphere is dominant in most individuals.[3,4] However, many other factors should be considered while selecting the approach side optimally. Aneurysm size, A1 dominance, A2 orientation, aneurysm dome direction, presence of anatomical variations, aneurysm neck accessibility, presence of gyrus rectus hematoma, previous surgeries, presence of other aneurysms, and personal preference have been described as additional relevant variables.[1,5,6] The surgeon's experience has also been considered a predictor of good outcomes.[7,8] On the other hand, there are centers who perform side choice on a case by case analysis. Previous studies have successfully predicted A1 dominance via analysis of computed tomography angiography (CTA) images, enabling faster decision-making regarding approach side in ACoAAs microsurgery.[9]

In this study, we present a retrospective analysis of a case series involving treatment of ACoAAs and discuss several aspects relevant to the selection of the approach side and factors related to the outcome.

Material and Methods

We reviewed the ACoAA cases treated microsurgically at a tertiary university hospital between April 2013 and December 2019. The data collection did not expose the patients to any additional intervention and the study was approved by the university's ethical committee. The study was performed at a tertiary university hospital, which is reference for neurosurgical cases to a population of approximately 1 million people.

Altogether, 116 patients with ACoAA were referred to our hospital. The treatment modality was decided based on the experience of the attending neurosurgeon. There were 41 patients who received endovascular treatment and were excluded from this analysis. As such, 75 patients underwent

microsurgical treatment. Only one patient was excluded because of incomplete records. Thus, 74 patients were considered eligible for inclusion in this study. Among these, 61 presented with SAH due to ACoAA rupture. The patients were treated by five attending neurosurgeons and neurosurgery residents. All attending neurosurgeons were right-handed.

Descriptive clinical data were obtained from the patients' medical records. The analyzed variables included age, sex, comorbidities, incidence of SAH, Fisher grade, Hunt-Hess score, World Federation of Neurosurgical Societies (WFNS) score, approach side, length of hospital stay, and mortality. Imaging studies were performed to measure the aneurysm size, direction, presence of gyrus rectus hematoma, neck size, and vessel dimensions on computed tomography (CT) scans. The anterior communicating complex vessels had diameters measuring approximately 0.5 cm from the anterior cerebral artery (ACA) insertion, and the larger A1/A2 was assumed to be dominant (►**Fig. 1**).

The computed tomography (CT) scans were obtained using Toshiba Activision 16 (Canon Medical System Corporation, Otawara, Japan) and GE Optima CT 660 (GE Healthcare, Chicago, IL, USA). Artis Zee (Siemens Medical Solutions, Inc., Malvern, PA, USA) was employed as the digital subtraction arteriography (DSA) suite. The diagnostic suite Arya (PACS Aurora 3.9.1; Pixeon, Florianopolis, SC, Brazil) was used to perform image analysis and measurements.

The DSA exam was performed in selected cases for better understanding of the anatomy and filling patterns of aneurysms that were considered more complex. A larger A1 was considered dominant for approach side indication in cases without DSA data. All patients were evaluated at 15 and 90 days after discharge, and a modified Rankin scale (mRS) score was assigned. The outcome was also analyzed based on the surgeon's experience. The mortality rate was compared between patients operated on by the senior surgeon of the group (M.A.Z.) and those operated on by the other four surgeons.

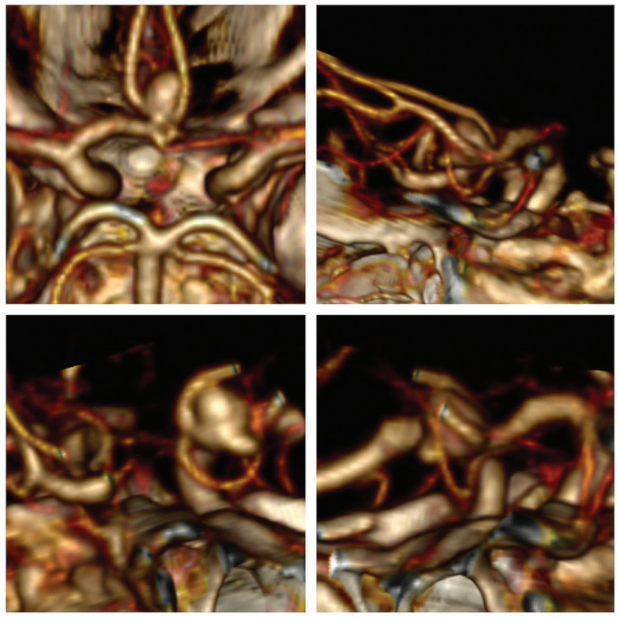

Fig. 1 Example of a case of subarachnoid hemorrhage. Direct measurements were made for A1, A2, aneurysm neck, and dome-neck size. Upper left figure shows the superior view of the Willis polygon, with an evident difference between the left and the right A1, which was a determining factor for selecting the approach side. Upper right figure shows the lateral view of the aneurysm, which was considered an anteriorly projected aneurysm during the analysis. The lower right figure represents the anterior right view of the lesion, while the lower left figure represents the anterior left view.

The Statistical Package Social Sciences (SPSS, IBM Corp., Armonk, NY, USA) software, version 19, was used for the statistical analysis. The quantitative data were examined for normality using the Shapiro–Wilk test. The normality hypothesis was rejected at $p < 0.05$. To evaluate the differences between the groups, quantitative data with normal distribution were tested with a two-sample *t*-test, while the non-normal variables were analyzed using the Mann–Whitney U test. Normal data were presented as means and non-normal data were presented as medians. Categorical variables were compared using the chi-squared test. A multivariate logistic regression was performed to further investigate the correlation between SAH-related mortality and the Hunt-Hess, Fisher, and WFNS scores. Survival results were compared between the senior neurosurgeon and the others using Cox regression.

Results

We studied 74 patients with a mean age of 56 years. Most of the patients were women (62.2%). There were 61 patients (82.2%) admitted with SAH and 13 were treated for unruptured intracranial aneurysms.

Altogether, 52% of the patients from our sample were smokers and 77% were hypertensive individuals. The median number of days until operation after the SAH episode was 3 and the longest delay for treatment was 27 days.

Most of the patients (51.4%) were treated using the right-side approach and 48.6% were treated using the left-side approach. Ages, comorbidities, and previous mRS scores did not differ between the approach sides for ruptured or unruptured aneurysms. In the unruptured aneurysm group, 61.5% were treated using the right-side approach, while 49.1% were treated using the right-side approach in the SAH group ($p = 0.545$).

The mean A1 diameters were 1.71 mm (standard deviation [SD] = 0.74) on the right and 1.81 mm (SD = 0.57) on the left side. The mean A2 diameters were 1.23 mm (SD = 0.41) on the right and 1.28 mm (SD = 0.38) on the left side. No significant differences were observed in vessel dimensions between the ruptured and unruptured aneurysms, or between the right and left-side approaches.

An association was identified between vessel side dominance and the selected approach side. For SAH patients, A1 dominance was associated with the approach side bilaterally ($p < 0.001$), while the association was weaker in patients with unruptured aneurysm. No significant association was observed between right-side dominance and the right-side approach for unruptured aneurysms ($p = 0.07$). However, the association between left-side dominance and the ipsilateral approach was significant ($p = 0.021$).

Table 1 Descriptive statistics, tables with means for normal and with medians for non-normal variables

	Total	Approach side		p-value
		Left	Right	
Age (years)	56.3	57.69	55.05	0.346
Delay for surgery (days)	3	2.5	3.00	0.540
In-hospital stay (days)	12	15	11	0.103
Days until mortality	17	17	18	0.332
Aneurysm dome-neck size (mm)	4.3	3.95	4.8	0.324
Aneurysm neck (mm)	2.64	2.59	2.69	0.603
Right A1 diameter (mm)	1.71	1.33	2.06	0.000
Right A2 diameter (mm)	1.23	1.11	1.33	0.021
Left A1 diameter (mm)	1.81	2.08	1.55	0.000
Left A2 diameter (mm)	1.28	1.42	1.15	0.002

There were 57 patients (77%) who did not present with gyrus rectus hematoma. The remaining 17 patients were distributed among right, left, and bilateral hematoma groups. No association was identified between gyrus rectus hematoma and the approach side ($p = 0.37$).

Approach and Side Comparison

Both the righ- and left-side approach groups were similar in terms of descriptive variables. There were 38 patients treated using the right-side approach and 36 using the left-side approach. The data are presented in ►**Tables 1** and **2**. Significant differences were observed between the groups in terms of hypertensive status ($p = 0.039$), with a greater number of hypertensive patients in the right-side approach group. A significant difference was observed between dimensions of the ACA branches depending on the approach side. The A1 and A2 branches were larger ipsilateral to the selected approach side. The mRS scores were similar between the groups.

The most common cranial approach was pterional craniotomy (67 cases, 90.5%). Among these cases, there were small custom-made variations of the classic pterional craniotomy. Orbitozygomatic (OZ) craniotomy was performed in five cases (6.7%). Among these, 4 patients had a superiorly projected aneurysm and one patient presented with a concomitant pericallosal artery aneurysm. Altogether, 22 superiorly projected aneurysms were treated. Among these, 18 were treated using the pterional approach. The patient who presented with a concomitant pericallosal aneurysm was treated using a bicoronal approach and one severely ill patient was treated with decompressive craniotomy.

There were 28 patients (37.8%) with at least one additional unruptured aneurysm. Among these, only three were not treated during the same surgery used to treat ACoAA. In 13 cases, surgical access was gained contralaterally to the dominant A1 side. Four of these cases had documented arteriographic filling from the smaller A1, while six cases had other contralateral brain aneurysms that were treated using the same procedure (5 middle cerebral artery aneurysms and 1 ophthalmic artery aneurysm). The remaining three cases had A1 size differences of 0.2 mm or less, which allowed for more freedom while selecting the approach side (all were operated from the right side).

Clinical Outcomes

None of the patients who underwent surgery for unruptured aneurysms experienced major complications and the mRS scores of this subgroup remained unchanged in all but one patient who exhibited an increase from a score of 1 preoperatively to a score of 2 after 3 months of follow-up. ►**Fig. 2** illustrates the prognostic distribution (distribution of mRS scores) within the whole group, the SAH group, and the unruptured aneurysm group.

Altogether, 21 patients died from SAH-related complications, with a mortality rate of 34.4% in this subgroup. All SAH patients, except one, were previously healthy and functional (mRS score of 2 or less). Among the survivors after a 3-month follow-up, 32 (52.4%) exhibited an mRS score of 2 or less and were still enrolled in rehabilitation programs.

Mortality was strongly correlated with the Hunt-Hess score ($r = 0.512$, $p < 0.001$), Fisher grade ($r = 0.46$, $p < 0.001$), and WFNS score ($r = 0.639$, $p < 0.001$), according to the Spearman correlation. No significant difference was found in mortality between the right and left-side approaches ($p = 0.253$, ►**Table 2**).

We performed a logistic regression analysis to further investigate the correlation between mortality and clinical scores. The WFNS scores independently predicted mortality ($p = 0.008$, odds ratio [OR] = 5.75, confidence interval [CI] = 1.584–20.903). The Fisher grades ($p = 0.137$, OR = 2.42, CI = 0.755–7.757) and Hunt-Hess scores ($p = 0.363$, OR = 0.53, CI = 0.141–2.049) were not independently associated with mortality.

The survival rate was significantly greater among patients operated on by the senior surgeon in the group (85 vs 61%, $p = 0.048$). All other examined variables were similar between the senior and non-senior groups. Survival curves for SAH patients who were operated on by the senior surgeon and for those who were operated on by other surgeons are depicted in ►**Fig. 3**. A Cox regression model developed to compare the senior and the non-senior groups identified a statistically significant difference ($p = 0.024$, ►**Fig. 3**).

Discussion

We have presented a retrospective case series of microsurgically treated ACoAAs. We performed descriptive analysis of the data obtained from 74 patients, including

Table 2 Qualitative variables and comparison between the right-side and left-side approaches

		N = 74 (%)	Approach side		*p*-value
			Left	Right	
Sex	Female	46 (62.2)	22	24	0.856
	Male	28 (37.8)	14	14	
Smoker	No	35 (47.2)	17	18	0.990
	Yes	39 (52.8)	19	20	
Hypertension	No	17 (23)	12	5	0.039
	Yes	57 (77)	24	33	
Diabetes	No	65 (87.8)	31	34	0.658
	Yes	9 (12.2)	5	4	
SAH	0	13 (17.5)	5	8	0.418
	1	61 (82.5)	31	30	
Hunt-Hess score	1	14 (23)	7	7	0.734
	2	14 (23)	6	8	
	3	11 (18)	5	6	
	4	19 (31)	12	7	
	5	4 (5)	1	2	
Fisher grade	1	6 (10)	3	3	0.671
	2	7 (11)	4	3	
	3	30 (50)	17	13	
	4	18 (30)	7	11	
WFNS score	1	19 (31)	9	10	0.549
	2	11 (18)	4	7	
	3	13 (21.3)	9	4	
	4	13 (21.3)	7	6	
	5	5 (8.4)	2	3	
Hydrocephalus	No	44 (59.5)	22	22	0.778
	Yes	30 (40.5)	14	16	
Decompressive craniotomy	No	67 (90.5)	32	35	0.637
	Yes	7 (9.5)	4	3	
Vasospasm	No	32 (43.2)	14	18	0.462
	Yes	42 (56.8)	22	20	
Direction	Anterior	24 (32.4)	14	10	0.059
	Upward	22 (29.7)	13	9	
	Downward	23 (31)	9	14	
	Posterior	5 (6.9)	0	5	
Mortality	No	53 (71.6)	28	25	0.253
	Yes	21 (28.4)	8	13	

Abbreviations: SAH, subarachnoid hemorrhage; WFNS, World Federation of Neurosurgical Societies.

38 treated using the right-side approach and 36 treated using the left-side approach. Both the groups were comparable, with significant differences only in the hypertensive status and in the A1-A2 vessel dimensions (►**Tables 1–2**). The SAH and unruptured aneurysm groups were also compared, revealing no significant differences in the previous descriptive data, but greatly different outcomes.

Patients treated for unruptured ACoAAs exhibited no worsening of the mRS scores after 3 months. In contrast, a general mortality rate of 34.4% was observed in the SAH group. Previous studies have reported mortality rates ranging from 10 to 26%.[10–13] A mortality rate of 20% was observed among SAH patients operated on by the senior surgeon, which was significantly different from that among those operated on by junior neurosurgeons ($p = 0.048$). Several studies have discussed the impact of vascular neurosurgery experience on surgical outcomes.[7,8,14,15] Since other relevant variables were statistically similar between the senior and the junior surgeon groups, we attribute the difference in the outcomes to the experience factor. In a previous study, Lawton and Du[16] described the influence of surgeons' experience on brain aneurysm surgery. The mortality rate declined, and the rate of favorable outcomes improved over time with surgical volume exposure.

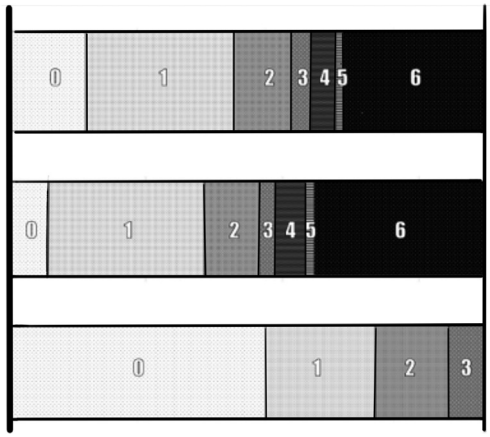

Fig. 2 Graph demonstrating the distribution of modified Rankin scale (mRS) scores after 3 months of follow-up. The first bar represents the distribution of the mRS scores within the whole group, the second bar represents the distribution within the SAH group, and the third bar represents the distribution within the unruptured aneurysm group.

As stated previously, higher Hunt-Hess scores, Fisher grades, and WFNS scores were strongly correlated with poorer outcomes. Mortality was also significantly correlated with hydrocephalus ($p = 0.03$), decompressive craniotomy ($p = 0.002$), and vasospasm ($p < 0.001$). After a 3-month follow-up, 32 patients in the SAH group (52.4%) exhibited an mRS score of 2 or less (►**Fig. 2**).

Classic pterional craniotomy accounted for 90.5% of the approaches used in this series. Other studies have reported the benefits of orbitopterional (OP) and OZ approaches.[17–19] High-riding, giant, and thrombosed ACoAAs may require upward-looking approaches.[19,20] In our series, five such cases demanded the OZ approach to reduce brain retraction. The remaining superiorly projected aneurysms were operated using the OP approach without any specific trend for complications. Brain relaxing maneuvers such as fissure splitting, liquor drainage, and dynamic retraction enabled successful treatment of these patients.

A marginal correlation between hypertension and the right-side approach was identified in our analysis ($p = 0.04$). Hypertension is a known risk factor for the development and rupture of brain aneurysms.[21] However, this association appears to be incidental.

Notably, A1 dominance was established through arteriography in 20 cases, resulting in 8 (40%) right-side dominant and 12 (60%) left-side dominant cases. The dominant A1 determined by arteriography was the same on the CT in 16 cases (80%). In four cases (20%), aneurysm filling originated from the smaller A1 on CT. A previous study predicted A1 dominance based on vessel size with an accuracy of 92.2%.[9] It is worth noting that even though DSA is the gold standard for aneurysm studies, it also results in additional radiation exposure and procedure-related risks.[9] Therefore, it was applied only to the aneurysms perceived to have a more complex structure in our case series.

The approach side has been the focus of discussion in many previous studies.[4] Our study demonstrated a spontaneous preference for the approach side based on the dimensions of the A1-A2 complex. The approach side was strongly correlated with the dominance of A1 and A2 observed on CTA. The presence of other treatable aneurysms also shifted the approach preference to an alternative that could treat more lesions. In four cases, the preference of approach side based on the CTA findings was changed due to the aneurysm filling pattern identified on DSA. Previous studies have reported a correlation between A1 dominance and the development of an ACoAA.[22,23] A recent study has also reported a correlation between dominant A2 and the

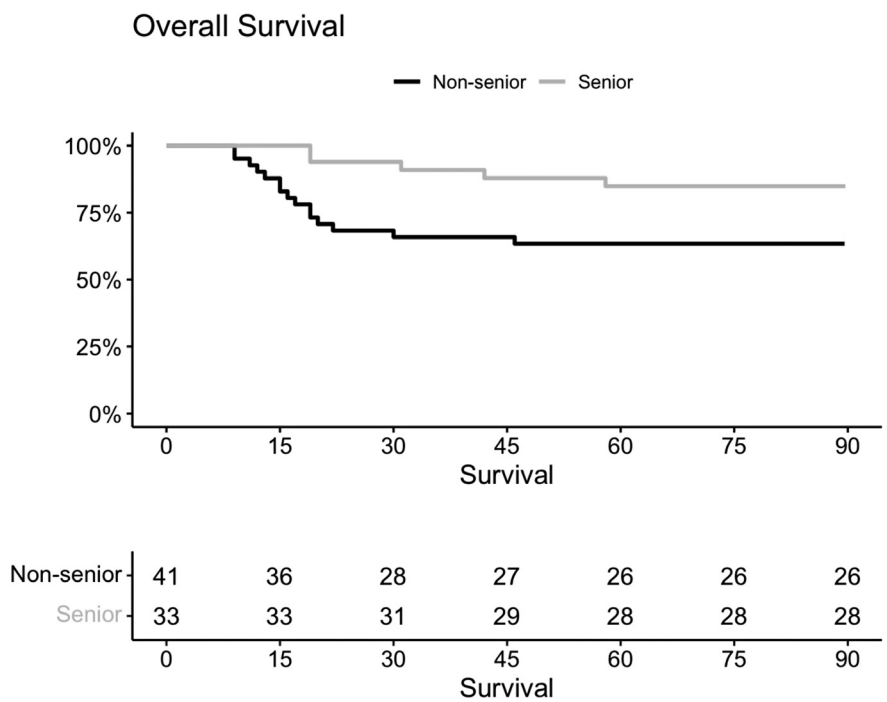

Fig. 3 Survival curves comparing the survival history between senior and non-senior surgeons revealed statistically significant difference ($p = 0.024$).

development and rupture of an ACoAA.[24] In our group, no difference in dominance was observed between the ruptured and unruptured aneurysms ($p = 0.578$).

It is worth mentioning that the present study has limitations that are inherent to retrospective studies. Additionally, it is a tendency of tertiary centers to receive patients with relatively more severe illnesses, which might have increased the mortality rate in this series. Another important limitation is that the results represent the experience of a single center. Multicenter studies are warranted to determine the external reproducibility of our findings.

Conclusions

At our center, A1 dominance was identified as a determining factor in selecting the approach side for SAH cases. A weaker association was observed between A1 dominance and the approach side for unruptured aneurysms. The existence of other unruptured aneurysms also influenced the selection of the approach side. We also demonstrated the effect of surgeons' experience on the outcomes in SAH patients, with a significant reduction in mortality among patients operated on by a more experienced surgeon. Understanding the factors involved in a ACoAA surgery remains a relevant and underexplored subject. Further studies involving larger case series and multicenter collaborations are necessary to elucidate these factors and to determine the external validity of our findings.

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Conflict of Interests
The authors have no conflict of interests to declare.

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