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Analysis of the Risk of Basilar Aneurysm Rupture Based on CTA Morphological Parameters

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Abstract: *Objective:* To investigate morphological risk factors of basilar aneurysm rupture based on computer tomography angiography (CTA) parameters. *Materials and methods:* The clinical and CTA data of 43 patients with basilar aneurysm admitted to Shaanxi Provincial People's Hospital from January 2015 to July 2023 were analyzed. The patients were divided into "ruptured group" and "unruptured group," and the morphological parameters of aneurysms were measured. The general data and morphological parameters between the two groups were statistically analyzed. Logistic regression was used to analyzed statistically significant parameters, and the receiver operating characteristic curve was drawn to evaluate its diagnostic effectiveness. *Results:* Irregular aneurysms were more likely to rupture than regular aneurysms ($x^2 = 13.971$, $P < 0.05$). The maximum diameter (4.92 [3.37–6.94] mm), length-width ratio (1.31 [1.14–1.55]), height (4.08 [2.71–5.34] mm), aspect ratio (0.99 [0.84–1.45]), and inflow angle (133.63 ± 11.21°) of aneurysms in the ruptured group were larger than the unruptured group, and the differences were statistically significant ($P < 0.05$). Binary logistic regression showed that aneurysm shape ($OR = 39.347$, $P = 0.021$), length-width ratio ($OR = 313.062$, $P = 0.033$), and inflow angle ($OR = 1.156$, $P = 0.004$) were independent risk factors for rupture. The area under the curve were 0.809, 0.842. and 0.894, respectively. *Conclusion:* Aneurysm shape, aspect ratio, and blood flow incidence angle are independent risk factors for basilar aneurysm rupture, which means that they can be used to predict the risk of rupture to a certain extent.

Keywords: Basilar origin aneurysm; Rupture; Tomography, Computed tomography; Risk factors

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1. Introduction

Cerebral aneurysms are focal abnormal dilations of cerebral arteries caused by weakened arterial walls due to arterial wall degeneration. The formation, occurrence, and rupture of such aneurysms are associated with inflammatory reactions. [1,2]. The incidence of intracranial aneurysms is about 3% [3], and vertebrobasilar aneurysms account for 5–16% [4]. Basilar artery aneurysm (BAA) typically has a high risk of rupture, accounting for around 3.9% of ruptures. [5]. A ruptured aneurysm can lead to severe nervous system complications like subarachnoid hemorrhage and cerebral hemorrhage, posing a life-threatening situation with a high mortality rate. Therefore, it is very important to evaluate the rupture risk of cerebral aneurysms. The size of the aneurysm is one of the key risk factors for bleeding in patients with unruptured cerebral aneurysms. Ruptured aneurysms are significantly larger than unruptured aneurysms [6], but the parameters in different parts are different. The utilization of follow-up imaging has led to an annual increase in the detection of aneurysms, with unruptured cases constituting approximately 2–10% of the general population. Many of these unruptured aneurysms may remain stable and not rupture [7]. However, managing apical basilar artery aneurysms and main basilar artery aneurysms presents challenges, often resulting in complications, residual aneurysms, or the need for retreatment following surgical clipping or endovascular treatment. [8,9]. Because of the mortality and morbidity related to its treatment, the benefits of treating these aneurysms must outweigh the potential complication risks, so the evaluation of the risk of rupture is crucial to determine the treatment for unruptured basilar artery aneurysms. In this study, we collected CTA data of BAA patients, measured their main morphological parameters, and discussed the relationship between morphological parameters and risk of rupture, so as to provide simple and feasible parameters for the evaluation of rupture of rupture for clinical practice, and better improve management and treatment of BAA.

2. Materials and methods

The data of patients who underwent CTA examination in Shaanxi Provincial People's Hospital from January 2015 to July 2023 and were diagnosed as BAA by surgery or digital subtraction angiography (DSA) were collected. This retrospective study was reviewed and approved by the Hospital Ethics Committee (Ethic No. 2022K-100).

2.1. Inclusion and exclusion criteria

All patients underwent CTA and were diagnosed by DSA or surgery. Exclusion criteria: (1) history of aneurysm surgery or cerebral infarction; (2) non-cystic aneurysm, (3) arterial dissection, (4) multiple aneurysms. Methods for evaluating aneurysm rupture include: (1) Identification of subarachnoid hemorrhage through CT plain scan and confirmation of a single aneurysm via CTA/DSA; (2) Indication of subarachnoid hemorrhage on plain CT scan, with active hemorrhage or contrast agent overflow visible during surgery or DSA.

2.2. Data collection

CTA was performed with Cannon Aquillion ONE 320-row or 640-slice CT scanner. The original data was exported in DICOM format, and post-processing analysis was carried out using a radiant DICOM viewer (https://www.radiantviewer.com/).

All CTA morphological parameters were evaluated and measured by experienced diagnosticians, and the location of aneurysm was identified, including basilar artery tip and basilar artery trunk (defined as aneurysm between vertebrobasilar junction and origin of superior cerebellar artery [8]). The aneurysm diameter, maximum diameter, width, height, parent artery diameter and inflow angle, were measured, and the length-width ratio (maximum diameter: tumor width), aspect ratio (aneurysm height: tumor diameter), and size ratio (aneurysm height: parent artery diameter) were calculated [10,11]. The VR images were categorized into irregular shape and regular shape based on the presence of vesicular shadow, lobulation, and daughter tumor in the aneurysm [12].

Arterial wall sclerosis is determined by identifying localized stenosis, calcified plaque, and mixed plaque in the carrier artery wall; if present, it indicates arteriosclerosis,

2.3. Statistical analysis

SPSS 25.0 was used to analyze the data: the number of ruptured group and non-ruptured group was expressed by the number of cases *n*, and a chi-square test was used for comparison between groups. Besides, Shapiro-

Wilk normal distribution test was performed on the data of two groups, and the coincidence was described mean ± standard deviation and independent sample *t*-test was used for comparison between groups. Mann-Whitney test was used to compare the parameters that did not conform to normal distribution. Logistic regression with R language (4.2.1) was used to estimate the independent risk factors of aneurysm rupture and the receiver operating characteristic curve (ROC) was plotted to evaluate the predictive efficiency ($P < 0.05$ was considered statistically significant).

3. Results

3.1. Descriptive analysis of the population

A total of 43 cases were included in this group, including 21 males and 22 females, aged 39–88 years, with an average 64.98 ± 10.07 years. Comparison of gender, age, arteriosclerosis and location of aneurysms between the two groups (**Table 1**).

Table 1. Comparison of gender, age, arteriosclerosis and location between non-ruptured group and ruptured group

Group	*n*	Gender		Age (years; mean ± standard deviation)	Arteriosclerosis		Location	
		Male	Female		Present	Not present	Apex	Trunk
Unruptured group	18	9	9	65.00 ± 9.31	6	12	12	6
Rupture group	22	12	13	64.96 ± 10.78	8	17	17	8
Statistical value		0.017[a]		0.805[b]	0.008[a]		0.008[a]	
P		0.897		0.990	0.927		0.927	

Note: *n*, number of cases; a, Chi-square test; b, *t-test*

3.2. Comparison of morphological parameters of aneurysms between the two groups

There was no significant difference in diameter and width of aneurysm or the diameter and size of parent artery between the two groups ($P > 0.05$). There were significant differences in shape, maximum diameter, length-width ratio, height, aspect ratio, and inflow angle between the two groups ($P < 0.05$), as shown in **Table 2**.

Table 2. Difference positive index of aneurysm morphological parameters

Group	Shape		Maximum diameter (mm)	Length-width ratio	Height (mm)	Aspect ratio	Inflow angle (°)	Group	Shape
	Regular	Irregular							
Unruptured group	14	4	3.13 (2.36–3.74)	1.03 (0.90–1.11)	2.54 (1.75–3.23)	0.69 (0.52–0.98)	110.9 ± 14.23	14	4
Rupture group	4	21	4.92 (3.37–6.94)	1.31 (1.14–1.55)	4.08 (2.71–5.34)	0.99 (0.84–1.45)	133.63 ± 11.21	4	21
Statistical value	13.971[c]	-2.782[d]	-3.816[d]	-2.487[d]	-2.290[d]	0.695[b]		13.971[c]	-2.782[d]
P	0.00	0.005	0.000	0.013	0.022	0.000		0.00	0.005

Note: b, *t*-test; c, modified chi-square test; d, Mann-Whitney U test

3.3. Logistic regression analysis

Table 3. Results of univariate and multivariate logistic regression analysis

Variables and grouping	N	Univariate analysis		Multivariate analysis	
		OR (95% CI)	*P-value*	OR value (95% CI)	*P-value*
Shape	43				
Rules	18	Reference		Reference	
Irregular	25	18.375 (3.931–85.891)	< 0.001	39.347 (1.749–885.048)	0.021
Maximum diameter (mm)	43	1.493 (1.051–2.122)	0.025	0.478 (0.044–5.149)	0.542
Length-width ratio	43	59.362 (2.245–1569.987)	0.015	313.062 (1.599–61281.2768)	0.033
Height (mm)	43	1.458 (0.993–2.138)	0.054	2.603 (0.164–41.238)	0.497
Aspect ratio	43	3.346 (0.835–13.414)	0.088	0.166 (0.003–10.225)	0.393
inflow angle (°)	43	1.160 (1.064–1.265)	< 0.001	1.156 (1.048–1.275)	0.004

Multivariate logistic analysis showed that there were significant differences in aneurysm shape, aspect ratio, and inflow angle between ruptured group and unruptured group by ($P < 0.05$), which were independent risk factors for aneurysm rupture.

3.4. Receiver operating characteristic (ROC) curve

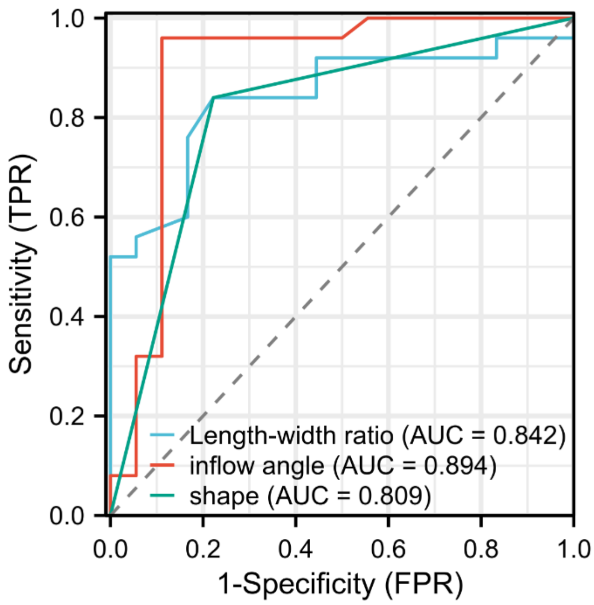

Figure 1. ROC curve analysis of shape, aspect ratio and inflow angle in diagnosing rupture

Table 4. AUC and ROC results of risk factors for aneurysm rupture

Variable	AUC	95% CI	Truncated value	Sensitivity	Specific degree
Shape	0.809	0.686–0.932	1.5	0.84	0.778
Length-width ratio	0.842	0.721–0.964	1.12	0.84	0.778
Inflow angle	0.894	0.770–1.000	120.6°	0.96	0.889

Table 5. AUC analysis

Variable 1	Variable 2	Statistics	p value	Inspection method	Trend
Length-width ratio	Inflow angle	-0.57056	0.5683	DeLong's test	Consistent
Length-width ratio	Shape	0.39438	0.6933	DeLong's test	Consistent
inflow angle	Shape	0.92409	0.3554	DeLong's test	Consistent

Table 5 shows that the trend of shape, aspect ratio and inflow angle is consistent, so there is no statistical significance in predicting the outcome.

4. Discussion

The purpose of this study is to explore the morphological measurement parameters of aneurysms based on CTA to help screen patients with high risk of BAA rupture. Basilar aneurysms can be divided into four subgroups: (1) basilar apex aneurysms, (2) basilar-superior cerebellar artery aneurysm; (3) basilar artery aneurysm; (4) vertebrobasilar junction aneurysms [4,8]. Basilar apex aneurysms and basilar-superior cerebellar artery aneurysms account for about 50% of vertebrobasilar aneurysms [4], while basilar trunk cystic aneurysms are relatively rare [8,13]. This study only includes aneurysms at the basilar trunk and basilar apex.

Generally speaking, due to the influence of estrogen, the proportion of female aneurysms is relatively high, and the proportion of female aneurysms in this group is 51.2%, but there is no significant gender difference between the two groups ($P > 0.05$). In addition, there was no statistical difference in age between rupture group and non-rupture group, and the average ages of rupture group and non-rupture group were 65 years old and 64.96 years old. There was no significant difference in terms of location distribution for the risk of rupture, which was presumed to be due to possible selection bias or small sample size. This study suggests that there is no statistical significance in the risk of rupture between the two groups, and it is also not related to the shape of aneurysm or the presence of arteriosclerosis [2].

In the comparison of morphological parameters, the results of this study showed that there were significant differences in the maximum diameter, aspect ratio, height, aspect ratio, and inflow angle between the two groups, and the median or average value of the ruptured group was slightly higher than that of the unruptured group. Multivariate binary logistic regression analysis suggested that the maximum diameter, height and aspect ratio of aneurysm were not independent risk factors for BAA rupture, and there was a certain degree of inaccuracy considering the change of diameter after aneurysm rupture [14]. It may be the result of aneurysm rupture, which will more reflect the actual clinical practice [15]. Irregular shape is an independent predictor of aneurysm rupture risk, which has been recognized by clinicians. Lauric *et al.* [16] also suggests that shape can predict aneurysm rupture more intuitively, that is, irregular aneurysm rupture poses a greater risk. Juchler *et al.* [17] suggested that there is a correlation between aneurysm size and shape, and the stimulation of aneurysm wall can affect the overall growth and morphological changes of aneurysm. A binary logistic analysis also showed that irregular aneurysms were more likely to rupture than regular aneurysms, indicating that irregular aneurysms were independent risk factors for the rupture of basilar aneurysms. This study shows that the risk of rupture of irregular aneurysms are 39.347 times higher than regular aneurysms, with good sensitivity and specificity, and the AUC is 0.809. This indicates that irregular aneurysms can be a reliable predictor of BAA rupture [6].. The aspect ratio is the ratio of the maximum diameter to the width. The larger the ratio, the slenderer the aneurysm and the higher the risk of rupture [11]. This study shows that the aspect ratio is a risk factor for rupture of basilar aneurysm, and the area under the curve is 0.842, which indicates certain accuracy. The incidence angle of blood flow is the angle between the maximum diameter of aneurysm and the center line of the parent artery. Skodvin *et al.* [11] showed blood flow with a larger incidence angle can make aneurysm prone to morphological changes and increase its rupture risk. The impact of internal blood flow in aneurysm can change its incident angle to a certain extent, making its shape more prominent and its wall thinner [10], further increasing the risk of rupture. Binary logistic regression analysis showed that the incidence angle of blood flow was an independent risk factor for BAA rupture, and the OR value was 1.12, which means that the risk of BAA rupture increased by 12% for every 1° increase in the incidence angle of blood flow. ROC curve analysis showed that the incidence angle of blood flow had high diagnostic efficiency for rupture, and the AUC was 0.894. The AUC showed that shape, aspect ratio, and incidence angle of blood flow were not statistically significant in predicting the outcome.

Basilar aneurysms can be treated by clipping or embolization. Metal analysis suggests that for basilar artery aneurysms, the incidence of complications, recurrence and re-intervention of endovascular treatment is higher [4]. Clinical and angiographic features of basilar artery aneurysms are diverse, so it is difficult to treat them, thus requiring multiple operations or techniques [8].

5. Limitations

This study is a retrospective study, and there might be some degree of bias in the data. Besides, the sample size is relatively small and the influence of vasospasm and subarachnoid hemorrhage on the measured values was not considered.

6. Conclusion

The anatomical location of basilar aneurysm is unique. CTA can predict the rupture risk of basilar aneurysm to a certain extent by measuring its shape, aspect ratio, and inflow angle, which will be helpful for its management and detection.

Disclosure statement

The authors declare no conflicts of interest.

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