Value of computed tomography angiography (CTA) measured aneurysm morphology and incidence angle

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► ***Short report***

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ABSTRACT

Background: The study investigates the relationship between aneurysm morphology and incidence angle measured by Computed Tomography Angiography (CTA) and the risk of intracranial aneurysm (IA) rupture. ***Materials and Methods:*** We analyzed data from 150 patients with intracranial aneurysms, comparing those with ruptured and non-ruptured aneurysms. Statistical methods were applied to identify key risk factors for rupture. ***Results:*** Significant differences were observed in aneurysm morphology, incidence angle, and risk scores between the ruptured and non-ruptured groups. Factors such as irregular aneurysm shape, larger diameter, aspect ratio (AR), size ratio (SR), and incidence angle were associated with higher rupture risk. ***Conclusion:*** CTA-measured aneurysm morphology and incidence angle, along with patient-specific factors, are crucial in assessing the risk of IA rupture. These findings can guide clinical decision-making and improve patient outcomes.

INTRODUCTION

Intracranial aneurysm (IA) is a prevalent intracranial vascular abnormality characterized by the weakening of a blood vessel wall in the brain, leading to a saccular dilation [1-3]. The primary risk associated with IAs is rupture, which results in subarachnoid hemorrhage, a critical medical emergency. Ruptured IAs can cause severe headaches, nausea, vomiting, disturbances in consciousness, and potentially death. Many IAs remain asymptomatic until rupture, often being incidentally discovered through brain imaging. The management of unruptured IAs involves assessing rupture risk to determine whether to monitor or intervene surgically or through endovascular treatment.

Recent studies emphasize the importance of aneurysm size, shape, and location as key factors influencing rupture risk [4, 5]. Larger aneurysms, those with irregular shapes, and those located in major arteries are more prone to rupture. Another factor under investigation is the incidence angle of the aneurysm, which is the angle between the aneurysm and the parent vessel [6-9]. However, there is ongoing debate about its significance as an independent risk factor. While some research supports a strong correlation between aneurysm morphology and incidence angle with rupture risk, other studies have found no significant difference in the incidence angle between ruptured and non-ruptured aneurysms, particularly in the ophthalmic artery segment [10-13].

This study aims to further clarify the relationship between aneurysm morphology, incidence angle, and rupture risk by analyzing clinical and Computed Tomography Angiography (CTA) measurement data from patients with both ruptured and unruptured aneurysms.

MATERIALS AND METHODS

Study design

The study enrolled 150 patients diagnosed with intracranial aneurysms at our hospital between January 2020 and January 2023. Patients with ruptured aneurysms were selected as the rupture group, and patients with non-ruptured aneurysms were selected as the non-ruptured group. The relevant clinical data of the two groups were retrospectively analyzed. Inclusion criteria: 1. IA was first diagnosed by DSA, and all of them were single aneurysm; 2. Complete clinical data; 3. CTA examination was performed and the image results were clear. Exclusion criteria: 1. Previous craniocerebral surgery or history of craniocerebral trauma; 2. Patients diagnosed with traumatic or infectious cerebral aneurysms; 3. Associated with vascular malformation; 4. Patients with malignant brain metastases, primary brain tumors or severe systemic diseases.

The age, gender, past medical history, personal history, family history and other clinical data of the two groups were collected through the hospital medical record system. This study was approved by the ethics committee. Ethical approval was obtained from the Quzhou Hospital Wenzhou Medical University Ethics Committee (Approval No. XYZ123, Date: January 10, 2020). All participants provided informed consent. Signed written informed consents were obtained from the patients and/or guardians.

CTA data

All subjects underwent CTA using a 128-slice spiral CT scanner (Ingenuity, Philips Healthcare, Netherlands). The scanning parameters were as follows: detector width 0.625 mm, thickness 0.625 mm, pitch 0.9, interval 0.300 mm, rotation time 0.5 s/turn, voltage 120 kVp, and current 200 mAs. The contrast agent used was ioversol (Optiray 320, Guerbet LLC, France), with 40–60 ml injected through the peripheral cubital vein at a rate of 4–5 ml/s prior to scanning. Scanning was performed from the aortic arch to the cranial fossa. Images were collected and uploaded to a workstation equipped with imaging analysis software (IntelliSpace Portal, Philips Healthcare, Netherlands) for further analysis. Two experienced diagnostic radiologists analyzed the images, measuring the aneurysm incidence angle (the angle between the centerline of the aneurysm and the plane projection of its maximum diameter), diameter (the maximum distance from the midpoint of the aneurysm neck to the apex of the aneurysm), aspect ratio (AR; the ratio of aneurysm height to neck width), and size ratio (SR; the ratio of aneurysm diameter to parent artery diameter). Typical CTA images at incidence angles are shown in figure 1.

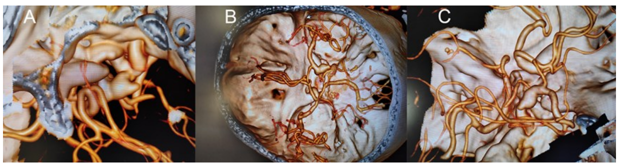

Figure 1. Typical CTA image at the angle of incidence. **A.** Incident angle = 60°. **B.** Incident angle = 90°. **C.** Incident angle = 120°.

Cerebral aneurysm rupture risk score (14) (PHASES score)

This scoring system can predict the risk of cerebral aneurysm rupture over the next 5 years. The score is based on the history of subarachnoid hemorrhage, aneurysm location, age, country, aneurysm size, and hypertension. The total score is 22 points, and the higher the score, the greater the risk of cerebral aneurysm rupture in the next 5 years.

Statistical analysis

Statistic Package for Social Science (SPSS) 26.0 (IBM, Armonk, NY, USA) was used for statistical analysis of the data. Numerical variables with normal distribution such as PHASES score were expressed as mean ± standard deviation ($\bar{x}$±s), and independent sample t test was used for comparison between groups. Disordered categorical variables such as aneurysm location were expressed as n (%), and the 2 test was used for comparison between groups. Binary Logistic regression analysis was used to determine the risk factors for aneurysm rupture in patients with IA. The test level was α=0.05.

RESULTS

Baseline information

A total of 150 patients with intracranial aneurysms admitted to our hospital from January 2020 to January 2023 were enrolled, including 75 patients with ruptured aneurysms and 75 patients with non-ruptured aneurysms. There were no significant differences in the average age, diabetes, hyperlipidemia, and family history of intracranial aneurysms (IA) between the two groups (P>0.05). However, the proportion of women, patients with a history of hypertension, smoking, and drinking in the ruptured group was significantly higher than in the non-ruptured group (P<0.05) (table 1).

Table 1. Comparison of baseline data between the two groups [(±s), n (%)].

Variables		Ruptured (n=75)	Non-ruptured (n=75)	t/c²	P
Gender (n)	Male	22 (29.33)	35 (46.67)	4.782	0.029
	Female	53 (70.67)	40 (53.33)		
Age (years)		58.72±7.49	57.37±7.16	1.128	0.261
Hypertension (n)	Yes	52 (69.33)	38 (50.67)	5.444	0.020
	No	23 (30.67)	37 (49.33)		
Diabetes (n)	Yes	19 (25.33)	17 (22.67)	0.146	0.702
	No	56 (74.67)	58 (77.33)		
Hyperlipemia (n)	Yes	14 (18.67)	12 (16.00)	0.186	0.666
	No	61 (81.33)	63 (84.00)		
Smoking (n)	Yes	37 (49.33)	24 (32.00)	4.669	0.031
	No	38 (50.67)	51 (68.00)		
Drinking (n)	Yes	42 (56.00)	28 (37.33)	5.250	0.022
	No	33 (44.00)	47 (62.67)		
Family history of IA (n)	Yes	9 (12.00)	7 (9.33)	0.280	0.597
	No	66 (88.00)	68 (90.67)		

Comparison of PHASES score and aneurysm location

The average PHASES score in the ruptured group was higher than that in the non-ruptured group (P<0.05), and there was no significant difference in the aneurysm location between the two groups (P>0.05) (table 2).

Comparison of CTA data

The proportion of irregular aneurysms in the ruptured group was higher than that in the non-ruptured group, and the incidence Angle, average diameter, AR and SR of aneurysms in the ruptured group were higher than those in the non-ruptured

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group (P<0.05) (table 3).

Table 2. Comparison of PHASES scores and aneurysm location between the two groups [(±s), n (%)].

Variables		Ruptured (n=75)	Non-ruptured (n=75)	t/c^2	P
PHASES score		5.72±1.26	4.87±1.34	4.002	<0.001
Aneurysm location (n)	Anterior cerebral artery	8 (10.67)	17 (22.67)	6.381	0.094
	Anterior communicating artery	16 (21.33)	12 (16.00)		
	Middle cerebral artery	20 (26.67)	14 (18.67)		
	Posterior communicating artery	18 (24.00)	13 (17.33)		
	Posterior cerebral circulation	13 (17.33)	19 (25.33)		

Table 3. Comparison of CTA measurement data between the two groups [(±s), n (%)].

Variables		Ruptured (n=75)	Non-ruptured (n=75)	t/c^2	P
Form (n)	Irregularity	48 (64.00)	29 (38.67)	9.634	0.002
	Regular	27 (36.00)	46 (61.33)		
Incident angle (°)		132.16±21.80	107.89±22.64	6.688	<0.001
Diameter of aneurysm (mm)		5.14±1.72	3.75±1.68	5.007	<0.001
AR		1.32±0.73	1.01±0.66	2.728	0.007
SR		2.36±0.81	1.52±0.74	6.631	<0.001

The influencing factors of IA rupture were analyzed by binary Logistic regression

Binary logistic regression analysis was conducted, with the presence or absence of aneurysm rupture in IA patients as the dependent variable (0=non-ruptured, 1=ruptured), and the significant variables from the univariate analysis as independent variables. The results indicated that female gender (OR=1.771), history of hypertension (OR=2.185), high PHASES score (OR=1.709), irregular aneurysm shape (OR=2.847), large aneurysm incidence angle (OR=1.058), large aneurysm diameter (OR=1.591), high AR (OR=3.245), and high SR (OR=5.300) were significantly associated with an increased likelihood of aneurysm rupture (P<0.05) (table 4).

Table 4. Binary logistic regression analysis of influencing factors for IA rupture and variable assignments.

Variable	β	SE	Wald	P	OR	95% CI	Assignment
Gender (Female)	0.572	0.394	2.104	0.037	1.771	1.012-3.836	1 = Female, 0 = Male
Hypertension	0.781	0.379	4.254	0.039	2.185	1.040-4.590	1 = Yes, 0 = No
PHASES score	0.536	0.145	13.671	<0.001	1.709	1.287-2.271	Continuous Variable
Aneurysm Form	1.046	0.362	8.34	0.004	2.847	1.400-5.792	1= Irregular, 0 = Regular
Incidence Angle	0.056	0.013	20.071	<0.001	1.058	1.032-1.084	Continuous Variable (Degrees)
Diameter of Aneurysm	0.464	0.162	8.249	0.004	1.591	1.159-2.184	Continuous Variable (mm)
AR	1.177	0.427	7.586	0.006	3.245	1.404-7.499	Continuous Variable
SR	1.668	0.369	20.391	<0.001	5.3	2.570-10.930	Continuous Variable

Note: PHASES = Population, Hypertension, Age, Size, Earlier subarachnoid hemorrhage, Site; AR = Aspect Ratio; SR = Size Ratio.

DISCUSSION

Intracranial aneurysms are a significant cause of intracranial hemorrhagic diseases. Although most aneurysms do not rupture, when rupture occurs, it can lead to severe consequences. The diagnosis and treatment of non-ruptured intracranial aneurysms remain a challenge due to the inability to accurately predict rupture risk, complicating clinical decision-making.

In this study, we explored the relationship between aneurysm morphology, incidence angle, and the risk of rupture using CTA measurements. Our findings revealed that factors such as gender, hypertension, smoking, and drinking history are associated with an increased risk of aneurysm rupture, which is consistent with previous studies [15-19]. Notably, female and hypertensive patients demonstrated a higher likelihood of aneurysm rupture, aligning with findings that estrogen can affect arterial wall structure and hypertension can cause vascular damage, both of which increase rupture risk.

Furthermore, we observed that patients in the ruptured group had higher PHASES scores, with aneurysm size, hypertension, age, and smoking contributing to this score. These findings corroborate previous studies that have identified PHASES score and aneurysm size as independent risk factors for rupture [20, 21].

Additionally, our study showed a higher prevalence of irregular aneurysm shapes, larger incidence angles, and increased AR and SR values in the ruptured group. These morphological characteristics have been linked to increased rupture risk due to factors such as turbulent blood flow, concentrated pressure points, and the relative size of aneurysms compared to their parent vessels. These results are in agreement with existing literature, which suggests that irregular shapes and larger incidence angles increase wall stress, thereby elevating rupture risk [22].

In summary, our findings underscore the importance of considering aneurysm morphology and CTA parameters in assessing rupture risk, contributing to more informed clinical decision-making. Further research should focus on validating these parameters across larger cohorts to refine risk prediction models.

Ethical compliance: This study was approved by the ethics committee of Quzhou Hospital, Wenzhou Medical University (Quzhou People's Hospital). Signed written informed consents were obtained from the patients and/or guardians.

Conflict of interest: The authors have no potential conflicts of interest to report relevant to this article.

Author contributions: YX and RZ designed the study and performed the experiments, YL and RL collected the data, AW and DM analyzed the data, YX and RZ

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REFERENCES

1. Rahmani R, Baranoski JF, Albuquerque FC, Lawton MT, Hashimoto T (2022) Intracranial aneurysm calcification - A narrative review. *Experimental Neurology*, ***353****: 114052*.
2. van den Berg R (2020) Intracranial aneurysm wall enhancement: fact or fiction? *Neuroradiology*, ***62****(3): 269-270*.
3. Sato H, Kamide T, Kikkawa Y, *et al*. (2021) Clinical characteristics of ruptured intracranial aneurysm in patients with multiple intracranial aneurysms. *World Neurosurgery*, ***149****: e935-e941*.
4. Lee MS, Kim MD, Lee M, Won JY, Park SI, Lee DY, Lee KH (2012) Contrast-enhanced MR angiography of uterine arteries for the prediction of ovarian artery embolization in 349 patients. *Journal of Vascular and Interventional Radiology*, **23** (9): 1174-9.
5. de Aguiar GB, Ozanne A, Elawady A, *et al*. (2022) Intracranial aneurysm in pediatric population: A single-center experience. *Pediatric Neurosurgery*, ***57****(4): 270-278*.
6. Wang Z, Liu Q, Wang D, Zhang N, Jiang H, Li H, *et al*. (2024) Secondary sequencing assisted diagnosis of pulmonary infection caused by Aspergillus oryzae in children with acute lymphoblastic leukemia: a case report. *International Journal of Radiation Research,* ***22(1)****: 229-233*.
7. Andrade L, Hoskoppal A, Hunt MM, *et al*. (2021) Intracranial aneurysm and coarctation of the aorta: prevalence in the current era. *Cardiology in the Young*, ***31****(2): 229-232*.
8. Caliskan E and Oncel D (2021) CT angiography evaluation of intracranial aneurysms: Distribution, characteristics, and association with subarachnoid hemorrhage. *Nigerian Journal of Clinical Practice*, ***24****(6): 833-840*.
9. Ferrari F, Cirillo L, Calbucci F, *et al*. (2019) Wall motion at 4D-CT angiography and surgical correlation in unruptured intracranial aneurysms: a pilot study. *Journal of Neurosurgical Sciences*, ***63****(5): 501-508*.
10. Wang GX, Yang Y, Liu LL, *et al*. (2021) Risk of rupture of small intracranial aneurysms (</=5 mm) among the Chinese population. *World Neurosurgery*, ***147****: e275-e281*.
11. Heros RC and Kistler JP (1983) Intracranial arterial aneurysm--an update. *Stroke*, ***14****(4): 628-631*.
12. Burns JD and Brown RJ (2009) Treatment of unruptured intracranial aneurysms: surgery, coiling, or nothing? *Current Neurology and Neuroscience Reports*, ***9****(1): 6-12*.
13. Jeong HW, Seo JH, Kim ST, Jung CK, Suh SI (2014) Clinical practice guideline for the management of intracranial aneurysms. *Neurointervention*, ***9****(2): 63-71*.
14. Juvela S (2022) PHASES score and treatment scoring with cigarette smoking in the long-term prediction of rupturing of unruptured intracranial aneurysms. *Journal of Neurosurgery*, ***136****(1): 156-162*.
15. Meyer FB, Morita A, Puumala MR, Nichols DA (1995) Medical and surgical management of intracranial aneurysms. *Mayo Clinic Proceedings*, ***70****(2): 153-172*.
16. Mittenentzwei S, Beuing O, Neyazi B, *et al*. (2021) Definition and extraction of 2D shape indices of intracranial aneurysm necks for rupture risk assessment. *International Journal of Computer Assisted Radiology and Surgery*, ***16****(11): 1977-1984*.
17. Waqas M, Rajabzadeh-Oghaz H, Tutino VM, *et al*. (2019) Morphologic parameters and location associated with rupture status of intracranial aneurysms in elderly patients. *World Neurosurgery*, ***129****: e831-e837*.
18. Skodvin TO, Evju O, Sorteberg A, Isaksen JG (2019) Prerupture intracranial aneurysm morphology in predicting risk of rupture: A matched case-control study. *Neurosurgery*, ***84****(1): 132-140*.
19. Zuurbier C, Molenberg R, Mensing LA, *et al*. (2022) Sex difference and rupture rate of intracranial aneurysms: An individual patient data meta-analysis. *Stroke*, ***53****(2): 362-369*.
20. Zhai XD, Yu JX, Li CJ, *et al*. (2020) Morphological characteristics of pericallosal artery aneurysms and their high propensity for rupture. *World Neurosurgery*, ***133****: e320-e326*.
21. Ma X, Yang Y, Liu D, Zhou Y, Jia W (2020) Demographic and morphological characteristics associated with rupture status of anterior communicating artery aneurysms. *Neurosurgical Review*, ***43****(2): 589-595*.
22. Lombarski L, Kunert P, Tarka S, Piechna A, Kujawski S, Marchel A (2022) Unruptured intracranial aneurysms: relation between morphology and wall strength. *Neurologia I Neurochirurgia Polska*, ***56*** *(5): 410-416*.

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