ORIGINAL ARTICLE

The effect of clinical, bifurcation, and aneurysm morphological characteristics on the risk of rupture in internal carotid artery bifurcation aneurysms

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ABSTRACT

BACKGROUND: This study aimed to examine the clinical and morphological characteristics associated with the risk of rupture of internal carotid artery (ICA) bifurcation aneurysms (ICAbifAn) by comparing ruptured and unruptured aneurysms.

METHODS: The two-center observational study included 66 patients with ICAbifAn (4.3%) identified from a database of 1,512 patients with intracranial aneurysms. The following data were collected and evaluated for their association with rupture risk: demographic data, medical history, aneurysm neck and dome size, bottleneck factor, aspect ratio (AR), size ratio, dome projection and localization, ICA (D1), M1, and A1 diameters, and ICA-M1 (β), ICA-A1 (γ), and M1-A1 (α) angles.

RESULTS: Sixty ICAbifAn cases were included in the study. Of these, 26 (43.3%) were ruptured aneurysms, and 34 (56.7%) were unruptured aneurysms. Patients in the ruptured group were younger than those in the unruptured group (p=0.017). The ruptured group had a smaller α angle (p=0.018) and significantly narrower A1 (p=0.004) and M1 (p=0.005) vessel diameters compared to the unruptured group. Irregular shape (p=0.001), AR>1.7, and a narrow neck (p=0.007) were significant predictors of rupture. Logistic regression analysis revealed that AR, α angle, and M1 and A1 diameters were significant predictors of aneurysm rupture. In receiver operating characteristic (ROC) analysis, an α angle cutoff of 126.2° exhibited a sensitivity of 61.5% and a specificity of 67.7% (area under the curve [AUC]=0.67). A cutoff M1 diameter of 2 mm exhibited a sensitivity and specificity of 61.5% and 76.4%, respectively (AUC=0.71). Additionally, a cutoff A1 diameter of 1.5 mm exhibited a sensitivity and specificity of 73.1% and 71.1%, respectively (AUC=0.75).

CONCLUSION: This study provided insights into the impact of aneurysm and bifurcation geometry on the risk of ICAbifAn rupture, which may also be applicable to more common bifurcation site aneurysms. Simple morphological measurements at the bifurcation region, where instability prevails, may serve as useful indicators for clinicians evaluating the likelihood of ICAbifAn rupture.

Keywords: Internal carotid artery bifurcation; aneurysm; ruptured; morphology; risk factor.

INTRODUCTION

The bifurcation of the internal carotid artery (ICA) is the apex of the Wills polygon and is subjected to significant hemodynamic stress.[1-3] Aneurysms in this region account for approximately 5% of all intracranial aneurysms and 15% of ICA aneurysms. These aneurysms tend to rupture at a younger age and are diagnosed at smaller sizes compared to aneurysms in other locations.[4] Intracranial aneurysm rupture is a catastrophic event, with a first-month mortality rate of 50% if left untreated, including ICA bifurcation zone aneurysms.[5] Therefore, identifying risk factors for aneurysm rupture is of great clinical importance, and research in this area continues to expand.

Cite this article as: Akdağ R, Gürpınar İ. The effect of clinical, bifurcation, and aneurysm morphological characteristics on the risk of rupture in internal carotid artery (ICA) bifurcation aneurysms. Ulus Travma Acil Cerrahi Derg 2025;31:283-290.

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Ulus Travma Acil Cerrahi Derg 2025;31(3):283-290 DOI: 10.14744/tjtes.2025.37680

Submitted: 10.11.2024 Revised: 04.02.2025 Accepted: 10.02.2025 Published: 03.03.2025

The increasing availability of diagnostic techniques has led to more people being diagnosed with unruptured aneurysms and has heightened the importance of clinical and hemodynamic assessments of individual aneurysm rupture risks. Hemodynamic factors are influenced by aneurysms and the surrounding vascular geometry. Additionally, various morphological risk factors for aneurysm rupture have been identified.[6-8] Due to the limited number of studies on internal carotid artery bifurcation aneurysms (ICAbifAn), particularly those based on morphological measurements, there is limited information regarding the natural history of these lesions. Thus, in this study, we focused on measurable parameters that are clinically practical and capable of predicting rupture. Our aim was to examine the clinical and morphological characteristics associated with the risk factors for ICAbifAn rupture by comparing ruptured and unruptured aneurysms.

MATERIALS AND METHODS

Study Participants and Inclusion/Exclusion Criteria

This observational study was conducted using a multicenter database that included 1,512 patients diagnosed with intracranial aneurysms who were admitted to Bursa Yüksek İhtisas Training and Research Hospital and Ankara City Hospital between July 2016 and December 2023. Among these, 64 patients with 66 ICAbifAn cases (4.3%) were consecutively enrolled in the study. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Bursa Yüksek İhtisas Training and Research Hospital Clinical Research Ethics Committee (Approval No: 2011-KAEK-25 2021/08-17, Date: 11 August 2021). Study parameters were categorized into two main groups: demographic and radiological.

Inclusion Criteria:

• Patients aged >18 years with a terminal ICAbifAn.

Exclusion Criteria:

• Fusiform and dissecting aneurysms.

• Isolated anterior cerebral artery (A1) and middle cerebral artery (M1) proximal aneurysms.

• Bilateral ICA bifurcation aneurysms.

• Patients with poor-quality imaging studies.

Demographic and Radiological Evaluation

The main demographic parameters considered were age, sex, hypertension, diabetes mellitus (DM), and smoking status. Computed tomography angiography was performed using a 128-slice computed tomography (CT) scanner, and three-dimensional (3D) reconstructed images were obtained (Philips Ing. Co., Philips Healthcare, Rotterdam, The Netherlands; scan parameters: 240 mA and 120 kVp). Images were interpreted using Synapse 3D (version V4.4EU; Synapse 3D Fujifilm Medical Systems, Greenwood, SC, USA). Additionally, 3D images were reconstructed using maximum intensity projections and volume rendering techniques (VRTs) with 10-mm slices. Each dataset was manually measured by both a primary physician and a radiologist, and the mean of the two measurements was used in the analysis.

Aneurysms were categorized based on morphological studies using the following parameters: aneurysm size, neck size, height, width, size ratio (SR), aspect ratio (AR), bottleneck ratio (BNR), aneurysm shape, and the presence of multiple aneurysms. The aneurysm size was determined by measuring the cross-sectional width at the widest point of the sac. Horizontal height (Hmax) was defined as the distance from the center of the neck to the furthest sac dome, while vertical height (H) was defined as the distance from the center of the neck to the uppermost dome. The BNR was calculated as the width-to-neck ratio of the aneurysm. The AR was defined as the ratio of the vertical height of the aneurysm to the neck size. The SR was defined as the ratio of aneurysm height to the mean diameter of the surrounding arteries.

The aneurysms were classified based on their anatomical location into three categories: true ICAbifAn, carotid-A1 junctional aneurysms, and carotid-M1 junctional aneurysms. Morphologically, the aneurysms were categorized into four classes: smooth surface, irregular surface, daughter sac (<50% of aneurysm size), and lobulated sac (>50% of aneurysm size). The orientation of the aneurysm was classified as superior, anterior, and posterior. Vessel angles as the ICA bifurcation were measured using the Towne projection. The angle between M1 and A1 was defined as α, the angle between the ICA and M1 was defined as β, and the angle between the ICA and A1 was defined as γ (Fig. 1). The diameters of the ICA, M1, and A1 vessels were measured using the formula: (Average diameter = [D1a + D2b] / 2).

Statistical Analysis

Statistical analyses were performed using IBM SPSS (version 29.0; IBM Corp., Armonk, NY, USA). The demographic and morphological characteristics of ruptured and unruptured aneurysms were compared to determine the risk factors for aneurysm rupture. Continuous data following a normal distribution are reported as means and standard deviations. Continuous variables without a normal distribution are presented as median, minimum, and maximum values. Categorical variables are expressed as numbers and percentages. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the normality of data distribution. Categorical differences in 2 × 2 tables were evaluated using Pearson's chi-square test and Fisher's exact test, while R × C tables were analyzed using the Fisher-Freeman-Halton test. The independent samples t-test was used to compare two groups with regular numerical components. The Mann-Whitney U test was used to compare the two non-normally distributed

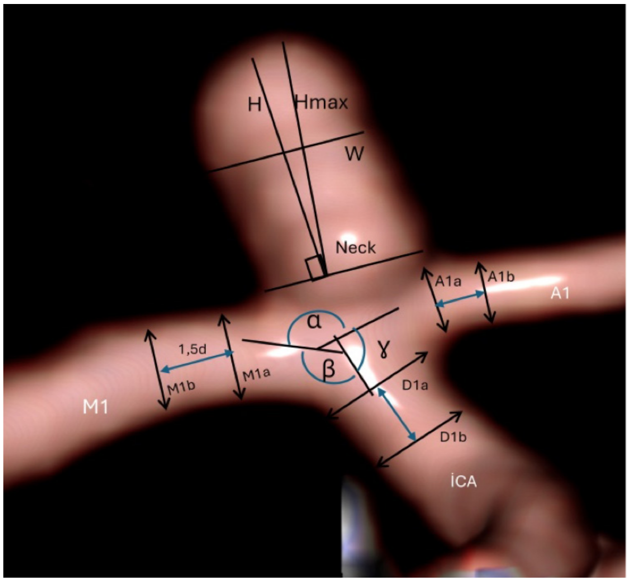

Figure 1. Computed tomography angiography (CTA) three-dimensional model of an internal carotid artery bifurcation aneurysm (ICAbifAn) depicting morphological variables of the surrounding vasculature.

A1: Anterior cerebral artery A1 segment; M1: Middle cerebral artery M1 segment; ICA: Internal carotid artery; α: M1-A1 bifurcation angle; β: Internal carotid artery-to-middle cerebral artery (ICA-to-M1) angle; γ: ICA-to-A1 angle; Neck: Aneurysm neck; H: Aneurysm height; Hmax: The furthest distance from the aneurysm neck to the aneurysm dome; W: Width of the aneurysm dome.

groups. Receiver operating characteristic (ROC) curve analysis was performed to assess the sensitivity and specificity of α, M1 diameter, and A1 diameter for specific values. A total of 2.5% of the case data were missing and were found to be uncorrelated with other factors. Therefore, missing data were excluded from the study. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 60 ICAbifAns were examined. Of these, 26 (43.3%) were ruptured aneurysms, while 34 (56.7%) were unruptured aneurysms. Among patients with ruptured aneurysms, nine were female and 17 were males, with a mean age of 41.9±14.1 years. In the unruptured group, 19 were female and 15 were male, with a mean age of 50.5±12.9 years. Patients in the ruptured group were significantly younger than those in the unruptured group (p=0.017). Table 1 presents the statistical analysis of clinical variables, focusing on hypertension, diabetes mellitus, smoking status, and the presence of multiple aneurysms.

There were no significant differences between the two groups in terms of aneurysm localization (p=0.885) and projection (p=0.669). However, a significant difference was observed in sac shape between the ruptured and unruptured groups (p=0.001). There were no significant differences in aneurysm size (p=0.129), BNR (p=0.783), and SR (p=0.782) between the two groups. However, the aneurysm neck size (p=0.007) and AR (p=0.027) were significantly lower in the ruptured group than in the unruptured group (Table 2).

There were significant differences in the α, M1, and A1 parameters but not in the β, γ, and D1 measurements between the groups. The α angle was significantly lower in the ruptured group than in the unruptured group [123±13.85° vs. 131±13.17°; p=0.018]. The M1 diameter was 1.9 mm (1.4-2.7) and 2.1 mm (1.4-3.2) in the ruptured and unruptured groups, respectively. The A1 diameter was 1.4 mm (0.6-2.2) and 1.7 mm (0.8-2.3) in the ruptured and unruptured groups, respectively. Both M1 (p=0.005) and A1 (p=0.004) diameters were significantly narrower in the ruptured group than in the unruptured group (Table 2).

In the univariate analyses, lower α (odds ratio [OR], 0.95;

Table 1. Demographic characteristics and clinical risk factors of study groups

	Group		
Characteristics	**Unruptured Group (n=34)**	**Ruptured Group (n=26)**	**p-value**
Age (years)†	51±13	42±14	0.017*
Sex‡			0.169*
Female	19 (55.9%)	9 (34.6%)	
Male	15 (44.1%)	17 (65.4%)	
Smoking‡	15 (44.1%)	14 (53.8%)	0.627*
Hypertension‡	15 (44.1%)	15 (57.6%)	0.434*
DM†	3 (8.8%)	4 (15.4%)	0.567*
Multiple Aneurysms	6 (17.6%)	5 (19.2%)	0.458*

‡Data are presented as n (%). †Data are presented as mean ± standard deviation. DM: Diabetes Mellitus. *Pearson Chi-Square test, Fisher's Exact test, or Fisher-Freeman-Halton test.

Table 2. Distribution of radiological aneurysm characteristics among the groups

	Group		
Characteristics	**Unruptured Group (n=34)**	**Ruptured Group (n=26)**	**p-value**
Aneurysmal Projection‡			0.855**
Anterior	8 (23.5%)	7 (26.9%)	
Superior	22 (64.7%)	17 (63.3%)	
Posterior	4 (11.7%)	2 (7.7%)	
Localization			0.669**
A1	11 (32.3%)	9 (34.6%)	
True	22 (64.7%)	15 (57.7%)	
M1	1 (2.9%)	2 (7.7%)	
Morphology			<0.001**
Flat	23 (67.6%)	0 (0%)	
Irregular	5 (14.7%)	14 (53.9%)	
Bleb	3 (8.8%)	7 (26.9%)	
Lobulated	3 (8.8%)	5 (19.2%)	
Neck Size (mm)§	2.8 [1.4-6.7]	2.0 [1.2-5.5]	0.007***
Aneurysm Size (mm)§	5.5 [3.0-15.1]	4.5 [3-15.2]	0.129***
BNR§	1.6±0.5	1.6±0.6	0.783*
AR†	1.8±0.36	2.1±0.65	0.027*
SR§	2.1 [0.9-4.3]	2.1 [0.8-5.1]	0.782***
α	131±13.17	123±13.85	0.018*
β	131.5 [82-153]	128 [110-156]	0.834***
ɣ	74.3±12.68	80.8±14.09	0.073*
D1 (mm)	2.6±0.45	2.5±0.39	0.246*
M1 (mm)	2.1 [1.4-3.2]	1.95 [1.4-2.7]	0.005***
A1 (mm)	1.7±0.34	1.4±0.36	0.004*

‡Data presented as n (%). †Data presented as mean ± standard deviation. §Data presented as median [minimum-maximum].*Independent Samples T-Test. **Pearson Chi-Square test, Fisher's Exact test, or Fisher-Freeman-Halton test. ***Mann-Whitney U test. A1: Anterior cerebral artery A1 segment; M1: Middle cerebral artery M1 segment; D1: Internal carotid artery (ICA); α: M1-A1 bifurcation angle; β: ICA-to-M1 angle; ɣ: ICA-to-A1 angle.

Table 3. Univariable and multivariable logistic regression analysis for ruptured internal carotid artery bifurcation aneurysms (ICAbIfAn)

	Univariate Analysis		Multivariate Analysis	
Variables	**Odds Ratio (95% CI)**	**p-value**	**Odds Ratio (95% CI)**	**p-value**
AR	3.72 (1.18-11.64)	0.024	2.74 (0.71-10.54)	0.143
α	0.95 (0.91-0.99)	0.023	0.95 (0.90-0.99)	0.028
M1	0.14 (0.03-0.62)	0.010	0.31 (0.04-2.48)	0.269
A1	0.10 (0.02-0.55)	0.008	0.17 (0.02-1.70)	0.132

A1: Anterior cerebral artery A1 segment; M1: Middle cerebral artery M1 segment; α: M1-A1 bifurcation angle.

Table 4. Comparison of diagnostic efficacy for different vascular morphological characteristics

	AUC	Cutoff	p	Sensitivity (%)	Specificity (%)
α	0.67 (0.54-0.74)	126.2	0.0137	61.54	67.74
M1	0.71 (0.58-0.82)	2	0.0018	61.54	76.47
A1	0.75 (0.62-0.86)	1.5	0.0003	73.1	71.1

A1: Anterior cerebral artery A1 segment; M1 Middle cerebral artery M1 segment; α: M1-A1 bifurcation angle.

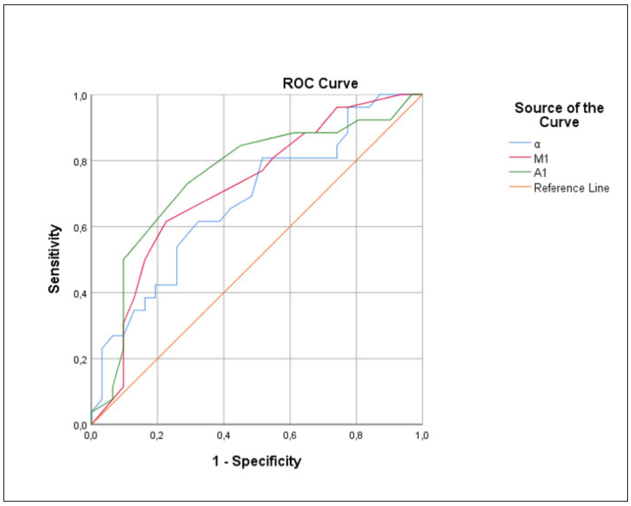

Figure 2. Receiver operating characteristic curves comparing the diagnostic efficacy of measured vascular morphological parameters, including the α (M1-A1) angle, M1 segment, and A1 segment.
A1: Anterior cerebral artery A1 segment; M1: Middle cerebral artery M1 segment; α: M1-A1 bifurcation angle.

95% confidence interval [CI]: 0.91-0.99), M1 (OR, 0.14; 95% CI: 0.03-0.62), and A1 (OR, 0.10; 95% CI: 0.02-0.55) values were significantly associated with ICAbifAn rupture. However, a higher AR (OR, 3.72; 95% CI: 1.18-11.64) was significantly inversely associated with ICAbifAn rupture. In the multivariate analysis, α (OR, 0.95; 95% CI: 0.90-0.99) was significantly associated with ICAbifAn rupture (Table 3).

The diagnostic ability of the α angle and the M1 and AI vessel diameters to predict aneurysm rupture was analyzed using ROC curve analysis (Fig. 2). The sensitivity and specificity were calculated for this value. The diagnostic value of the test was statistically significant when the type I error in the area under the curve (AUC) assessment was <5%. A cutoff α angle of 126.2° (AUC=0.67) exhibited a sensitivity of 61.5% and a specificity of 67.7%. A cutoff M1 vessel diameter of 2 mm (AUC=0.71) exhibited a sensitivity of 61.5% and a specificity of 76.4%. Furthermore, a cutoff A1 vessel diameter of 1.5 mm (AUC=0.75) exhibited a sensitivity of 73.1% and a specificity of 71.1% (Table 4).

DISCUSSION

The ICA is one of the three most common sites of intracranial aneurysms (36-40%). Because ICAbifAns are rare, they are often included with ICA aneurysm ruptures in prospective observational studies.[2,9,10] Furthermore, existing studies have primarily focused on treatment modalities and aneurysm outcomes.[2–5,11-16] In this clinical and morphological study, we demonstrated that irregular lobulated aneurysms with a smaller α angle, narrower M1 and A1 diameters, a higher AR, and a smaller aneurysm neck size are associated with ICAbifAn rupture. Additionally, we found that aneurysms in this region tend to rupture at younger ages. Although some studies indicate that characteristics such as female sex, middle to older age, smoking history, presence of DM or hypertension, and multiple aneurysms influence aneurysm rupture, other studies suggest that these variables are not significant risk factors for rupture.[8,17,18] In our study, age was the only variable associated with ICAbifAn rupture. Furthermore, the average age of patients with ruptured aneurysms was 41.6 years, which is considered young and was statistically significant. Intracranial aneurysm rupture is most commonly observed in the 5th and 6th decades of life.[19,20] However, ICAbifAns have been reported to rupture at younger ages, which is one of their most striking characteristics. Additionally, most aneurysms in children and adolescents are located at the ICA bifurcation (39-50%). Studies have reported that the mean age of patients with a ruptured ICAbifAn is ≤40 years.[12,15,16] Our findings are consistent with those in the literature.

The results regarding the role of morphological parameters in predicting aneurysm rupture are heterogeneous in the literature. Identifying predictive factors for rupture risk is crucial for the effective screening of patients with intracranial aneurysms. Morphological factors such as aneurysm size, neck width, AR, BNR, SR, aneurysm location, perianeurysmal circumference, and irregular aneurysm shape have been reported to play a decisive role in rupture risk.[7,8,18,20-23] Similar to other intracranial aneurysms and in accordance with findings in the literature, an irregularly shaped dome, AR>1.7, and a narrow neck were important determinants of rupture in our study. However, aneurysm size, BNR, and SR were not significant determinants of aneurysm rupture. A prospective study on the prognosis of unruptured aneurysms demonstrated that the most important risk factors of rupture were location, the presence of daughter aneurysms, and larger aneurysm size.[9] In a retrospective analysis of over 2,000 patients, an AR>1.6, a dome diameter>10 mm, and a thin neck were identified as individual risk factors for rupture.[24] Kleinloog et al.[22] calculated the pooled OR for irregular shape and AR in aneurysm rupture to be 4.8 and 10.2, respectively. Furthermore, they concluded that an irregular shape, in particular, is a morphological risk factor for aneurysm rupture and should be considered in clinical practice. The notion that aneurysm irregularity is correlated with a higher risk of rupture is consistent with our findings. We hypothesize that the lack of a significant correlation between aneurysm size and rupture risk in our study, which is inconsistent with findings in the literature, may be due to the relatively medium-to-large unruptured aneurysms that were diagnosed incidentally after the widespread use of diagnostic tools.

Since aneurysm dome hemodynamics are influenced by the diameters of the parent and daughter arteries, bifurcation, and aneurysm geometry, different mechanisms may contribute to biological changes in the aneurysm wall over time. This process involves a complex interplay of cause-and-effect interactions that result in aneurysm sac growth and eventual rupture.[25,26] Wall shear stress (WSS) at the bifurcation has been associated with aneurysm formation and rupture. WSS is influenced by bifurcation geometry, including the radii of all vessels and the bifurcation angle.[27,28] In our study, ruptured ICAbifAns had smaller α angles and narrower M1 and A1 vessel diameters than unruptured aneurysms. However, there was no significant difference in ICA vessel diameter (D1) between the groups. In a study on basilar artery aneurysm, one of the two T-type aneurysms, Rashad et al.[26] reported that ICAbifAn rupture may be associated with bifurcation geometry. They found that as the angulation of both posterior cerebral arteries decreases (i.e., as the bifurcation angle increases), aneurysm neck WSS increases due to direct blood flow into the aneurysm sac, which may lead to aneurysm rupture. Alnaes et al.[1] designed blood models and observed that differences in vessel radius and asymmetric branch angles affect the magnitude and spatial distribution of WSS. A recent study also reported that asymmetric bifurcation may cause aneurysm wall damage by inducing abnormally high hemodynamic stress at the bifurcation site.[29] In contrast, two separate studies on middle cerebral artery and basilar artery aneurysm hemorrhages found that increased vessel angulation and a larger diameter of distal vascular structures were associated with aneurysm rupture.[30,31] These conflicting results may be attributed to the type of aneurysm evaluated (bifurcation vs. sidewall). Based on our findings, we propose that two variables contribute to the increased likelihood of aneurysm wall rupture. The first is the increased jet flow of blood from the primary artery into the aneurysm, which occurs due to a decrease in the α angle. The second is the larger vortex and more abnormal hemodynamic stress at the bifurcation site, resulting from increased resistance caused by narrower M1 and A1 vessel diameters. Our findings indicate that aneurysm wall resistance may decrease due to the increased WSS at the aneurysm neck.

The primary limitations of this study are its retrospective design and limited sample size. Another limitation is the lack of correlation between hemodynamic factors (WSS and oscillatory shear index [OSI]) and morphometric factors, both of which reportedly play important roles in aneurysm formation and rupture. These factors have limited clinical utility due to the complexity, time consumption, and high cost of measurement. Additionally, measurements were conducted manually rather than automatically, which may have introduced minor inconsistencies in the results. However, this technique is more suitable for clinical practice.

CONCLUSION

This study provides insights into the impact of aneurysm and bifurcation geometry on the risk of ICAbifAn rupture, and its findings may be applicable to other, more common bifurcation-site aneurysms. Our findings demonstrate that simple morphological measurements at the bifurcation region, where chaotic flow prevails, may serve as useful indicators for clinicians assessing the risk of ICAbifAn rupture.

Ethics Committee Approval: This study was approved by the Bursa Yüksek İhtisas Training and Research Hospital Clinical Research Ethics Committee (Date: 11.08.2021, Decision No: 2011-KAEK-25 2021/08-17).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: R.A., İ.G.; Design: R.A., İ.G.; Supervision: R.A., İ.G.; Resource: R.A., İ.G.; Materials: R.A., İ.G.; Data Collection and/or Processing: R.A., İ.G.; Analysis and/or Interpretation: R.A., İ.G.; Literature Review: R.A., İ.G.; Writing: R.A., İ.G.; Critical Review: R.A., İ.G.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

REFERENCES

1. Alnaes MS, Isaksen J, Mardal KA, Romner B, Morgan MK, Ingebrigtsen T. Computation of hemodynamics in the circle of willis. Stroke 2007;38:2500–5. [CrossRef]
2. La Pira B, Brinjikji W, Burrows AM, Cloft HJ, Vine RL, Lanzino G. Unruptured internal carotid artery bifurcation aneurysms: General features and overall results after modern treatment. Acta Neurochir (Wien) 2016;158:2053–9. [CrossRef]
3. Morales-Valero SF, Brinjikji W, Murad MH, Wald JT, Lanzino G. Endovascular treatment of internal carotid artery bifurcation aneurysms: A single-center experience and a systematic review and meta-analysis. AJNR Am J Neuroradiol 2014;35:1948–53. [CrossRef]
4. Mahmoud M, Farag A, Farid M, Elserwi A, Abdelsamad A, Guergues W, et al. Application of flow diverters in the treatment of aneurysms in the internal carotid artery bifurcation region. Neuroradiol J 2020;33:297–305. [CrossRef]
5. Liu X, Guo Y, Zhang K, Yu J. Endovascular treatment of intracra-

nial internal carotid artery bifurcation region aneurysms. Front Neurol 2024;15:1344388. [CrossRef]
6. Can A, Du R. Association of hemodynamic factors with intracranial aneurysm formation and rupture: Systematic review and meta-analysis. Neurosurgery 2016;78:510–20. [CrossRef]
7. Detmer FJ, Chung BJ, Jimenez C, Hamzei-Sichani F, Kallmes D, Putman C, et al. Associations of hemodynamics, morphology, and patient characteristics with aneurysm rupture stratified by aneurysm location. Neuroradiology 2019;61:275–84. [CrossRef]
8. Wang GX, Wen L, Yang L, Zhang QC, Yin JB, Duan CM, et al. Risk factors for the rupture of intracranial aneurysms using computed tomography angiography. World Neurosurg 2018;110:e333–8. [CrossRef]
9. UCAS Japan Investigators; Morita A, Kirino T, Hashi K, Aoki N, Fukuhara S, Hashimoto N, et al. The natural course of unruptured cerebral aneurysms in a Japanese cohort. N Engl J Med 2012;366:2474–82. [CrossRef]
10. Wiebers DO, Whisnant JP, Huston J 3rd, Meissner I, Brown RD Jr, Piepgras DG, et al; International Study of Unruptured Intracranial Aneurysms Investigators. Unruptured intracranial aneurysms: Natural history, clinical outcome, and risks of surgical and endovascular treatment. Lancet 2003;362:103–10. [CrossRef]
11. Chung J, Park W, Park JC, Kwun BD, Ahn JS. Characteristics of peri-internal carotid artery bifurcation aneurysms according to a new anatomic classification: How to overcome difficulties in the microsurgical treatment of posteroinferiorly projecting carotid-A1 junctional aneurysms. World Neurosurg 2019;126:e1219–27. [CrossRef]
12. Gupta SK, Khosla VK, Chhabra R, Mohindra S, Bapuraj JR, Khandelwal N, et al. Internal carotid artery bifurcation aneurysms: Surgical experience. Neurol Med Chir (Tokyo) 2007;47:153–7. [CrossRef]
13. Konczalla J, Platz J, Brawanski N, Güresir E, Lescher S, Senft C, et al. Endovascular and surgical treatment of internal carotid bifurcation aneurysms: Comparison of results, outcome, and mid-term follow-up. Neurosurgery 2015;76:540–50. [CrossRef]
14. Lee WJ, Cho YD, Kang HS, Kim JE, Cho WS, Kim KM, et al. Endovascular coil embolization in internal carotid artery bifurcation aneurysms. Clin Radiol 2014;69:e273–9. [CrossRef]
15. Miyazawa N, Nukui H, Horikoshi T, Yagishita T, Sugita M, Kanemaru K. Surgical management of aneurysms of the bifurcation of the internal carotid artery. Clin Neurol Neurosurg 2002;104(2):103–14. [CrossRef]
16. Shivhare P, Vaidya P, Garhwal G, Raj N, Gohil J, Sawant N, et al. ICA bifurcation aneurysms: Clinical features and surgical outcome in a tertiary referral center in South India. Turk Neurosurg 2021;31:318–23. [CrossRef]
17. Doddasomayajula R, Chung B, Hamzei-Sichani F, Putman CM, Cebral JR. Differences in hemodynamics and rupture rate of aneurysms at the bifurcation of the basilar and internal carotid arteries. AJNR Am J Neuroradiol 2017;38:570–6. [CrossRef]
18. Ma J, Zheng Y, Li P, Zhou T, Sun Z, Ju T, et al. Risk factors for the rupture of intracranial aneurysms: A systematic review and meta-analysis. Front Neurol 2023;14:1268438. [CrossRef]
19. Etminan N, Chang HS, Hackenberg K, de Rooij NK, Vergouwen MDI, Rinkel GJE, et al. Worldwide incidence of aneurysmal subarachnoid hemorrhage according to region, time period, blood pressure, and smoking prevalence in the population: A systematic review and meta-analysis. JAMA Neurol 2019;76:588–97. [CrossRef]
20. Wermer MJ, van der Schaaf IC, Algra A, Rinkel GJ. Risk of rupture of unruptured intracranial aneurysms in relation to patient and aneurysm characteristics: An updated meta-analysis. Stroke 2007;38:1404–10. [CrossRef]
21. Johnson MD, Palmisciano P, Yamani AS, Hoz SS, Prestigiacomo CJ. A systematic review and meta-analysis of 3-dimensional morphometric parameters for cerebral aneurysms. World Neurosurg 2024;183:214–26.
22. Kleinloog R, de Mul N, Verweij BH, Post JA, Rinkel GJE, Ruigrok YM. Risk factors for intracranial aneurysm rupture: A systematic review. Neurosurgery 2018;82:431–40. [CrossRef]
23. Wang GX, Liu LL, Yang Y, Wen L, Duan CM, Yin JB, et al. Risk factors for the progression of unruptured intracranial aneurysms in patients followed by CT/MR angiography. Quant Imaging Med Surg 2021;11:4115–24. [CrossRef]
24. Nieuwkamp DJ, Setz LE, Algra A, Linn FH, de Rooij NK, Rinkel GJ. Changes in case fatality of aneurysmal subarachnoid haemorrhage over time, according to age, sex, and region: A meta-analysis. Lancet Neurol 2009;8:635–42. [CrossRef]
25. Hao W, Yang L, Cao X, Huang X, Wang X, Zhang X. Cerebral arterial bifurcations harboring D type aneurysm are more asymmetrical than those with C type aneurysm. J Stroke Cerebrovasc Dis 2021;30:105972. [CrossRef]
26. Rashad S, Sugiyama SI, Niizuma K, Sato K, Endo H, Omodaka S, et al. Impact of bifurcation angle and inflow coefficient on the rupture risk of bifurcation type basilar artery tip aneurysms. J Neurosurg 2018;128:723–30. [CrossRef]
27. Ćmiel-Smorzyk K, Kawlewska E, Wolański W, Hebda A, Ładziński P, Kaspera W. Morphometry of cerebral arterial bifurcations harbouring aneurysms: A case-control study. BMC Neurol 2022;22:49. [CrossRef]
28. Tang Y, Wei H, Zhang Z, Fu M, Feng J, Li Z, et al. Transition of intracranial aneurysmal wall enhancement from high to low wall shear stress mediation with size increase: A hemodynamic study based on 7T magnetic resonance imaging. Heliyon 2024;10:e30006. [CrossRef]
29. Zhang XJ, Hao WL, Zhang DH, Gao BL. Editorial expression of concern: Asymmetrical middle cerebral artery bifurcations are more vulnerable to aneurysm formation. Sci Rep 2022;12:1036. [CrossRef]
30. Sadatomo T, Yuki K, Migita K, Taniguchi E, Kodama Y, Kurisu K. Morphological differences between ruptured and unruptured cases in middle cerebral artery aneurysms. Neurosurgery 2008;62:602–9. [CrossRef]
31. Tütüncü F, Schimansky S, Baharoglu MI, Gao B, Calnan D, Hippelheuser J, et al. Widening of the basilar bifurcation angle: Association with presence of intracranial aneurysm, age, and female sex. J Neurosurg 2014;121:1401–10. [CrossRef]

ORİJİNAL ÇALIŞMA - *ÖZ*

IKA bifurkasyon anevrizmalarında klinik, bifurkasyon ve anevrizma morfolojik özelliklerinin rüptür riski üzerine etkisi

AMAÇ: Bu çalışmada, yırtılmış anevrizmaları yırtılmamış anevrizmalarla karşılaştırarak internal karotid arter (ICA) bifurkasyon anevrizmalarının (ICAbifAn) yırtılma riskiyle ilişkili klinik ve morfolojik özellikleri incelemeyi amaçladık.

GEREÇ VE YÖNTEM: İki merkezli gözlemsel çalışmaya, intrakraniyal anevrizması olan 1512 hastadan oluşan bir veritabanından tanımlanan 66 ICA-bifAn hastasını (%4.3) dahil ettik. Aşağıdaki veriler toplandı ve yırtılma riskiyle ilişkili olup olmadıkları açısından değerlendirildi: demografik veriler, tıbbi geçmiş, anevrizma boynu ve kubbe boyutu, darboğaz faktörü, en/boy oranı (AR) ve boyut oranı, kubbe projeksiyonu ve lokalizasyonu, ICA (D1), M1 ve A1 çapları ve ICA–M1 (β), ICA–A1 (γ) ve M1–A1 (α) açıları.

BULGULAR: Çalışmaya altmış ICAbifAn vakası dahil edildi. Bunlardan 26'sı (%43.3) yırtılmış ve 34'ü (%56.7) yırtılmamış anevrizmalardı. Yırtılan grup yırtılmamış gruptan daha gençti (p=0.017). Yırtılan grubun daha küçük bir α açısı (p=0.018) ve yırtılmamış gruba göre önemli ölçüde daha dar A1 (p=0.004) ve M1 (p=0.005) damar çapları vardı. Düzensiz şekil (p=0.001), AR >1.7 ve dar boyun (p=0.007) yırtılmanın önemli öngörücüleriydi. Lojistik regresyon analizi, AR, α açısı ve M1 ve A1 çaplarının anevrizma yırtılmasının önemli öngörücüleri olduğunu ortaya koydu. ROC analizinde, 126.2°'lik bir α açı kesme değeri %61.5 duyarlılık ve %67,7 özgüllük gösterdi (AUC=0,67). 2 mm'lik bir kesme M1 çapı sırasıyla %61.5 duyarlılık ve %76.4 özgüllük gösterdi (AUC=0.71). Ayrıca, 1,5 mm'lik bir kesme A1 çapı sırasıyla %73.1 duyarlılık ve %71.1 özgüllük gösterdi (AUC=0.75).

SONUÇ: Bu çalışma, anevrizma ve bifurkasyon geometrisinin ICAbifAn rüptürü riski üzerindeki etkisine dair içgörüler sağladı ve bu, diğer daha yaygın bifurkasyon bölgesi anevrizmalarına uygulanabilir. Kaosun hakim olduğu bifurkasyon bölgesindeki basit morfolojik ölçümler, ICAbifAn rüptürü olasılığını değerlendiren klinisyenler için yararlı göstergeler olabilir.

Anahtar sözcükler: Anevrizma; internal karotid arter bifurkasyonu; morfoloji; risk faktörü; yırtılmış.

Ulus Travma Acil Cerrahi Derg 2025;31(3):283-290 DOI: 10.14744/tjtes.2025.37680