Alternative Definitions of Cerebral Aneurysm Morphologic Parameters Have an Impact on Rupture Risk Determination

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■ BACKGROUND: **A discrepancy between definitions of morphologic parameters describing cerebral aneurysms across studies leads to conflicting results concerning performances of these factors and threshold values for rupture status prediction. The aim of the study was to evaluate how various definitions of morphologic parameters may influence the prediction of the risk for aneurysm rupture.**

■ METHODS: **A total of 425 intracranial aneurysms were reviewed. Analyzed factors included demographic and clinical parameters, aneurysm maximal height (Hmax), dome length (Dlength), dome width (Dwidth), dome maximal diameter (Dmax) and dome minimal diameter (Dmin), neck length (Nlength), neck width (Nwidth), and neck maximal diameter (Nmax) and neck minimal diameter (Nmin). Alternative definitions of aspect ratio (AR), bottleneck factor (BNF), and height-to-width ratio (HW) were used. Univariate and multivariate analysis were performed to identify predictors for aneurysm rupture.**

■ RESULTS: **Hmax, AR defined as Hmax/Nwidth and Hmax/Nmin, BNF definitions using Nwidth and Nmin, and selected definitions of HW (Hmax/Dlength and Hmax/Dmin) were indicated as potential predictors for rupture. Aneurysm location was found to be a confounding factor with statistical significance. AR defined as Hmax/Nwidth and Hmax/Nmin were the best performers ($P < 0.001$; area under the curve, 0.64). In multivariate analysis, AR defined as Hmax/Nwidth and aneurysm location with significantly higher risk for rupture of anterior communicating artery aneurysms were independent predictors for subarachnoid hemorrhage.**

■ CONCLUSIONS: **Different definitions of aneurysm parameters affect various rupture risk determination. AR defined as Hmax/Nwidth and aneurysm location with significantly higher rupture risk of anterior communicating artery aneurysms are independent predictors for aneurysm rupture.**

INTRODUCTION

Indications for treatment of unruptured intracranial aneurysms are controversial, and the benefit of treating these aneurysms must outweigh the potential risks of complications.[1] To minimize the risk of treatment-related adverse events, it is desirable to identify risk factors for aneurysm rupture. It is widely known that aneurysm size is one of the most important key risk factor for hemorrhage among patients with unruptured cerebral aneurysms; however, a role of this parameter as a predictor for rupture has not been unequivocally established.[2,3] One of the reason is that to date there is no unique definition for measuring aneurysm size.[4,5] Previously, Lauric et al.[5] reviewed aneurysm size definitions reported in the literature and the most commonly cited definitions were "maximal dimension of the aneurysmal dome," "maximal projection from the aneurysm dome to the neck plane," or "maximal longitudinal diameter parallel to the neck plane."[5-11] It is also noteworthy that many authors in their publications do not define aneurysm size at all.[5] Such discrepancy of

Key words
- Intracranial aneurysm
- Morphology
- Rupture

Abbreviations and Acronyms
AR: Aspect ratio
AUC: Area under the curve
BNF: Bottleneck factor
Dlength: Dome length
Dmax: Dome maximal diameter
Dmin: Dome minimal diameter
Dwidth: Dome width
Hmax: Aneurysm maximal height
HW: Height-to-width ratio
Nlength: Neck length
Nmax: Neck maximal diameter
Nmin: Neck minimal diameter
Nwidth: Neck width
SAH: Subarachnoid hemorrhage

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Citation: World Neurosurg. (2019) 126:e157-e164. https://doi.org/10.1016/j.wneu.2019.01.283

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

1878-8750/$ - see front matter

Table 1. Definitions of the Most Common Morphologic Parameters Characterizing Intracranial Aneurysms in the Literature

Parameter	Definitions
Aneurysm size	■ Maximal dimension of dome ■ Maximal orthogonal projection of dome to neck plane ■ Maximal longitudinal diameter parallel to neck plane
Aneurysm height	■ Maximal distance from neck to aneurysm dome ■ Maximal orthogonal distance from aneurysm dome to neck plane ■ Maximal orthogonal distance from neck to aneurysm dome
Aneurysm width	■ Maximal longitudinal diameter of dome parallel with neck plane ■ Maximal width of dome orthogonal to maximal height
Neck size	■ Maximal neck diameter ■ Minimal neck diameter ■ Average neck diameter
Aspect ratio	■ Maximal distance from neck to aneurysm dome/maximal neck width ■ Maximal distance from neck to aneurysm dome/minimal neck width ■ Maximal distance from neck to aneurysm dome/average neck size ■ Maximal orthogonal projection of dome to neck plane/maximal neck width ■ Maximal orthogonal projection of dome to neck plane/minimal neck width ■ Maximal orthogonal projection of dome to neck plane/average neck size ■ Maximal orthogonal distance from neck to aneurysm dome/maximal neck width ■ Maximal orthogonal distance from neck to aneurysm dome/minimal neck width ■ Maximal orthogonal distance from neck to aneurysm dome/average neck size ■ Maximal longitudinal diameter parallel with the neck plane/maximal neck width ■ Maximal diameter of dome/maximal neck width
Bottleneck factor	■ Maximal width of dome orthogonal to maximal height/maximal neck diameter ■ Maximal width of dome orthogonal to maximal height/minimal neck diameter ■ Maximal width of dome orthogonal to maximal height/average neck diameter ■ Maximal longitudinal diameter of dome parallel with neck plane/maximal neck diameter ■ Maximal longitudinal diameter of dome parallel with neck plane/minimal neck diameter ■ Maximal longitudinal diameter of dome parallel with neck plane/average neck diameter
Height/width ratio	■ Maximal distance from neck to aneurysm dome/maximal width of dome orthogonal to maximal height ■ Maximal orthogonal projection of dome to neck plane/maximal longitudinal diameter of dome parallel with neck plane ■ Maximal orthogonal distance from neck to aneurysm dome/maximal longitudinal diameter of dome parallel with neck plane
Size ratio	■ Maximal aneurysm height/parent vessels mean diameter ■ Maximal aneurysm size/parent vessels mean diameter
Aneurysm angle	■ Angle between aneurysm neck and maximum aneurysm height
Vessel angle	■ Angle between parent vessel feeding into aneurysm and neck plane
Flow angle	■ Angle between vector of maximum aneurysm height and centerline vector of parent vessel
Parent-daughter vessel angle	■ Angle between flow vector of parent and daughter vessels

definitions across studies may lead to conflicting results presented in the literature concerning the performance of aneurysm size. It may have an impact on the difficulty of determining a reliable size threshold value for rupture status prediction.[5]

In addition to size, other simple morphologic characteristics, such as aneurysm height and aneurysm neck diameter, may be used to identify aneurysms at risk for rupture, but their definitions and performances are also inconsistent across studies.[12] Among commonly reported more complex factors that may offer some predictive value for rupture are aspect ratio (AR), bottleneck factor (BNF), and height-to-width ratio (HW).[10,12-15] The general definition of AR is "height-to-neck ratio" and BNF definition is "width-to-neck ratio," and similarly to the simple geometrical parameters there is no consensus of measurement method or threshold values.[5,10,12-16] The most common morphologic parameters characterizing intracranial aneurysms in the literature are presented in Table 1.

In this study we have analyzed various morphologic factors to screen the potential predictors for hemorrhage in patient-derived aneurysm data. The aim of the study was to evaluate how the variable definitions of these parameters may have statistical implications for prediction of the risk for aneurysm rupture.

MATERIALS AND METHODS

Patients and Aneurysms

We retrospectively reviewed a total of 388 consecutive patients diagnosed with 425 intracranial aneurysms between February 2008 and March 2015 at our institution. There were 314 women (73.9%) and 111 men (26.1%). The mean age was 53.08 years (range, 19–81 years). There were a total of 285 unruptured (67.1%) and 140 ruptured aneurysms (32.9%). Only intradural saccular aneurysms were included in the study. Detailed demographic and clinical data are presented in Table 2.

Table 2. Demographic and Clinical Features Between Ruptured and Unruptured Aneurysms

Characteristic	Unruptured (n = 285)	Ruptured (n = 140)	*P* Value
Age (years)	53.8 ± 10.4	51.9 ± 12.9	0.1
Female sex	76.1	69.3	0.09
Smoking	41.8	34.3	0.14
Hypertension	46.7	43.6	0.36
Family history	13.3	9.2	0.23
Multiple aneurysms	9.1	7.9	0.66
Undulation formation	10	11.6	0.63
History of prior SAH	5	7.36	0.35
Location			
AComA	52 (18.2)	64 (45.7)	<0.001
MCA	94 (33)	23 (16.4)	
ICA	106 (37.2)	39 (27.9)	
Posterior circulation	33 (11.6)	14 (10)	

Values are mean ± SD, %, or as otherwise indicated.
SAH, subarachnoid hemorrhage; AcomA, anterior communicating artery; MCA, middle cerebral artery; ICA, internal carotid artery.

Angiographic Data Processing

All aneurysms were determined and measured using 3-dimensional rotational angiography. All examinations were performed using a flat panel angiographic unit (Philips Integris V, Workstation 3D-RA Release 4.2, Philips Healthcare, Eindhoven, Netherlands). The files were converted from the native format (.v3d) to a.dcm format. The measurement of the parameters was carried out on RadiAnt 4.2.1 software (Medixant, Poznan, Poland). The default 3-dimensional visualization method used for the measurement process was a maximum intensity projection reconstruction. Aneurysm parameters were analyzed in 3 projections (Figures 1 and 2). In every case, the aneurysm neck plane was defined to our best ability as the location from where the aneurysmal sac pouched outward from the parent vessel in accordance with Dhar et al.[7]

Definitions of Morphologic Parameters

We used morphologic parameters reported in previous studies (Figure 1).[5,10,12,17,18] Aneurysm maximal height (Hmax) was the largest distance between the neck center and aneurysm surface that could be fitted inside the dome.[5] Dome maximal diameter (Dmax) was defined as the longest distance between 2 points on the cross-sectional area of the aneurysm dome parallel to the neck plane. Dome minimal diameter (Dmin) was the shortest distance between 2 points of the aneurysm dome on the cross section parallel to the neck plane. Dome length (Dlength) was the longest distance between 2 points of the aneurysm dome parallel to the long axis of the parent vessel, and dome width (Dwidth) was defined as the longest distance between 2 points of the aneurysm dome that was perpendicular to the long axis of the parent vessel. Neck maximal diameter (Nmax) was the longest distance between 2 points of the aneurysm neck passing through the neck center, defined as the centroid (geometric center) of the neck region. Neck minimal diameter (Nmin) was the shortest distance between 2 points of the aneurysm neck passing through the neck center. Neck length (Nlength) was defined as the longest distance between 2 points of the aneurysm neck parallel to the long axis of the parent vessel, and neck width (Nwidth) was the longest distance between 2 points of the aneurysm neck perpendicular to the long axis of the parent vessel.

Complex morphologic parameters, such as AR, HW, and BNF, were characterized by 4 different definitions of aneurysm dome (Dmax, Dmin, Dlength, and Dwidth) and neck (Nmax, Nmin, Nlength, and Nwidth), and 1 definition of aneurysm height (Hmax). This resulted in 4 AR alternative definitions (Hmax/Nmax, Hmax/Nmin, Hmax/Nlength, and Hmax/Nwidth) and 4 HW definitions (Hmax/Dmax, Hmax/Dmin, Hmax/Dlength, and Hmax/Dwidth). BNF, described by 4 definitions for dome size and 4 definitions of neck size, resulted in 16 different definitions (Dmax/Nmax, Dmax/Nmin, Dmax/Nlength, Dmax/Nwidth, Dmin/Nmax, Dmin/Nmin, Dmin/Nlength, Dmin/Nwidth, Dlength/Nmax, Dlength/Nmin, Dlength/Nlength, Dlength/

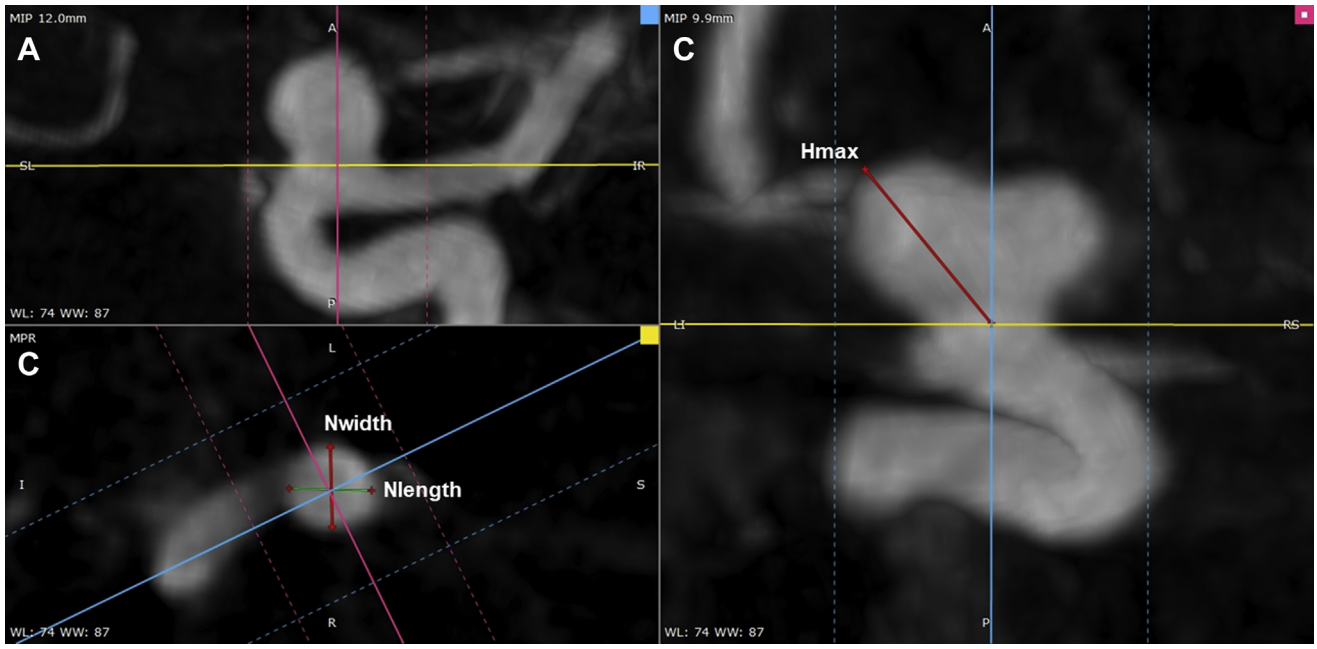

Figure 1. An illustrative example presenting measurement of an internal carotid artery aneurysm. Maximum intensity projection images obtained via digital subtraction angiography were used. After demonstration of an aneurysm (**A**), the suitable measurement planes were chosen (*color lines*) and then the neck width, neck length (**B**), and aneurysm maximal height (**C**) were evaluated. The other analyzed parameters are not depicted in this notional picture. Hmax, aneurysm maximal height; MIP, maximum intensity projection; Nlength, neck length; Nwidth, neck width.

Nwidth, Dwidth/Nmax, Dwidth/Nmin, Dwidth/Nlength, and Dwidth/Nwidth).

Statistical Analyses

Statistical analyses were performed using SAS 9.4 software (SAS Institute, Inc., Cary, North Carolina, USA). The continuous data were presented as mean ± SD, and categorical variables were expressed as frequency (%). Demographic and clinical data were analyzed for differences by rupture status with the use of χ^2 tests and t tests for binary and continuous variables, respectively. To identify potential variables associated with subarachnoid hemorrhage (SAH), analysis of variance tests were performed before and after adjusting for confounding factors (i.e., aneurysm location as a covariate). SAH was used as the dependent variable in this model. The area under the curve (AUC) of the receiver operating characteristics were computed. Bonferroni correction was applied to control family-wise error. The multivariate logistic regression model included covariates found to have a marginal association with SAH in the univariate analysis (defined as $P < 0.05$) and was performed with the application of the forward regression method after controlling for aneurysm location. $P < 0.05$ was considered statistically significant. Odds ratios and 95% confidence intervals were calculated. To estimate methodologic reliability, the interobserver variability was evaluated with the intraclass correlation coefficient for 9 parameters (Hmax, Nmin, Nmax, Nwidth, Nlength, Dmin, Dmax, Dwidth, and Dlength).[19] The intraclass correlation coefficient values were interpreted according to Koo and Li.[19] Correlation values <0.5 represent poor reliability, values from 0.5 to 0.75 represent moderate reliability, values from 0.75 to 0.9 represent good reliability, and values >0.9 represent excellent reliability.[19]

Ethics Statement

For this retrospective study, ethics committee approval and informed patient consent were waived. The patients' information was anonymized and de-identified prior to analysis.

RESULTS

The analyzed demographic and clinical data except for aneurysm location did not differ between patients with unruptured and ruptured aneurysms.

In univariate analysis, Hmax was found to be the only potential predictor for aneurysm rupture ($P < 0.001$; AUC, 0.55) among all simple morphologic parameters. None of the parameters characterizing the cross-sectional area of the aneurysm dome (Dmin, Dmax, Dwidth, and Dlength) or neck (Nmin, Nmax, Nwidth, and Nlength) achieved statistical significance in univariate analysis.

Among the complex parameters in univariate analysis, AR defined as Hmax/Nwidth and Hmax/Nmin and the BNF definitions using Nwidth and Nmin were indicated as potential predictors for SAH. In case of HW, 2 definitions (Hmax/Dlength and Hmax/Dmin)

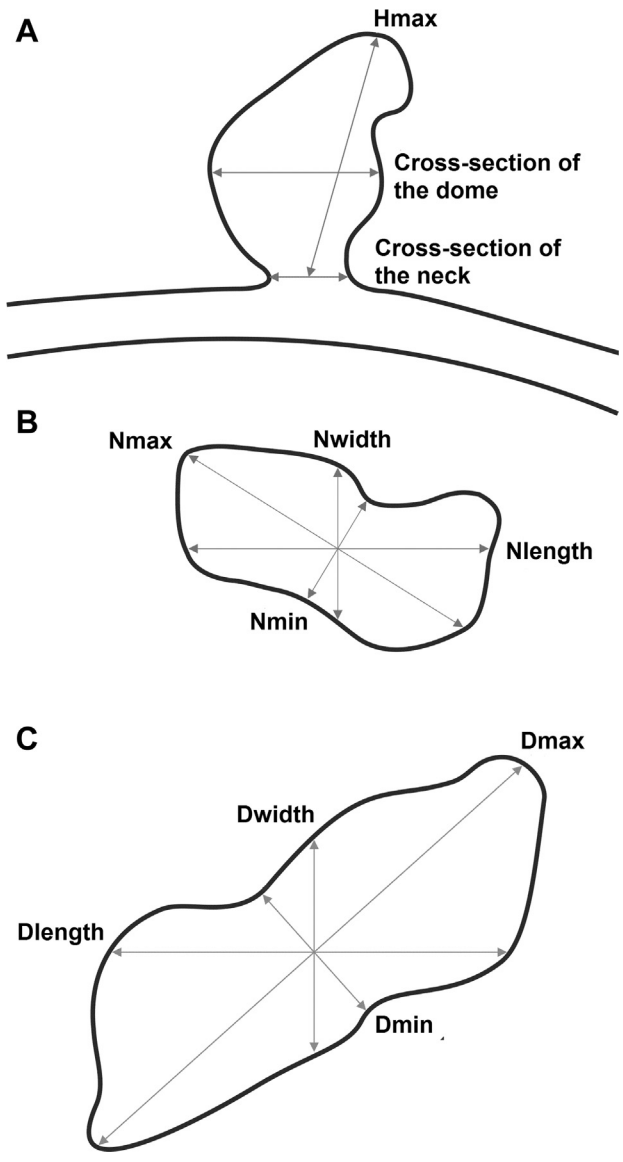

Figure 2. Schematic drawing illustrating aneurysm dome (**A**) and transverse cross sections of aneurysm dome (**B**) and aneurysm neck (**C**). Dlength, dome length; Dmax, dome maximal diameter; Dmin, dome minimal diameter; Dwidth, dome width; Hmax, aneurysm maximal height; Nlength, neck length; Nmax, neck maximal diameter; Nmin, neck minimal diameter; Nwidth, neck width.

were found to be potential predictors for aneurysm rupture in univariate analysis performed without adjusting for aneurysm location.

AR defined as Hmax/Nwidth and Hmax/Nmin were the best performers ($P < 0.001$; AUC, 0.64). Results of the univariate statistical analysis with the use of size parameters evaluated in the study are listed in Table 3.

In multivariate analysis, AR defined as Hmax/Nwidth and aneurysm location with significantly higher risk for rupture of anterior communicating artery aneurysms were independent predictors for SAH. The receiver operating characteristic analysis identified optimal threshold value for rupture prediction as 1.45 using Hmax/Nwidth.

The general measure of interobserver agreement for all measurements is provided in Table 4.

DISCUSSION

Our study shows that the image-based morphologic factors that are potential predictors for aneurysm rupture are Hmax, Hmax/Nwidth, Hmax/Nmin, Hmax/Dlength, and Hmax/Dmin and the BNF definitions using Nwidth and Nmin. As far as Hmax is concerned, this parameter is frequently used to characterize the aneurysm size in many reports. In the literature, Hmax is the most common geometrical parameter used to predict aneurysm rupture; however, the definitions of Hmax across studies are inconsistent.[12] Hmax when defined as the largest distance from the neck center to the aneurysm dome is reported to have the highest performance in discriminating rupture status in comparison with other parameters representing the aneurysm size (i.e., maximal diameter of the dome, maximal orthogonal distance from the neck to aneurysm dome, maximal orthogonal projection of the dome to the neck plane).[5] Hence, only the one definition of Hmax was analyzed in the current publication. The receiver operating characteristic analysis identified the optimal threshold value for rupture prediction as 3.91 mm for Hmax in our report. This value is lower than the one presented in the International Study of Unruptured Intracranial Aneurysms (7–10 mm), but it is consistent with many retrospective reports suggesting that aneurysms with a size <5 mm rupture frequently.[3,20,21] In all these studies, however, a disparate aneurysm sizing methodology was applied; therefore, a comparison among these research papers seems to be unreliable.

According to the previous reports on risk factors for aneurysm rupture, cross-sectional measurements of the aneurysm dome are occasionally taken into consideration in terms of the evaluation of rupture risk of cerebral aneurysms.[5,12,15,16] The cross-sectional dimensions evaluated in our publication, such as Dmax, Dmin, Dlength, and Dwidth, were not associated with aneurysm rupture. It has been previously shown that the width of the aneurysm dome as a predictor for aneurysm rupture should be rather interpreted together with aneurysm height (i.e., HW ratio) or Nwidth (i.e., BNF).[12] These 2 complex parameters are reported to play a certain role in determining aneurysm rupture risk that was confirmed by the results of the present study.[12]

The findings of the literature provide conflicting results regarding the size of an aneurysm neck as a predictor for aneurysm rupture.[5,12,22-24] In most studies, the size of the neck of an intracerebral aneurysm is not related to rupture status discrimination.[5,12,25-27] In the study by Wang et al.,[23] longer width of the neck, defined as the largest cross-sectional diameter of the aneurysm neck, was associated with aneurysm rupture ($P < 0.001$). Ho et al.[22] reported that larger neck of posterior communicating artery aneurysms was an independent predictor for rupture ($P = 0.048$), but the neck size was not clearly defined in that study. The results of our study suggest that neck diameter may not serve as a determinant for aneurysm rupture. None of 4 analyzed neck size definitions in the current report were statistically significant in univariate analysis.

Table 3. Univariate Analysis Results for the Evaluated Morphologic Parameters Before and After Adjustment for Aneurysm Location

Parameter	Ruptured Mean	Unruptured Mean	*P* Value	*P* Value After Adjustment for Aneurysm Location	AUC
Hmax	6.92 ± 3.86	6.15 ± 3.22	<0.001*	<0.001*	0.55
Dwidth	6.99 ± 3.98	6.51 ± 3.31	6.56	>0.99	0.52
Dlength	6.48 ± 3.64	6.33 ± 3.10	20.26	>0.99	0.49
Dmax	7.54 ± 4.09	7.08 ± 3.50	8.09	>0.99	0.52
Dmin	5.96 ± 3.36	5.75 ± 2.71	17.11	>0.99	0.49
Nwidth	4.04 ± 1.7	4.59 ± 1.96	0.13	0.81	0.61
Nlength	4.65 ± 2.17	4.79 ± 2.05	16.55	>0.99	0.54
Nmax	4.92 ± 2.13	5.14 ± 2.10	10.15	>0.99	0.55
Nmin	3.76 ± 1.59	4.23 ± 1.80	0.23	0.49	0.60
Aspect ratio					
Hmax/Nwidth	1.80 ± 0.90	1.41 ± 0.67	<0.001*	<0.001*	0.64
Hmax/Nlength	1.59 ± 0.84	1.38 ± 0.77	0.43	0.1	0.60
Hmax/Nmin	1.94 ± 0.97	1.55 ± 0.80	<0.001*	<0.001*	0.64
Hmax/Nmax	1.46 ± 0.69	1.25 ± 0.59	0.07	0.06	0.60
Height/width					
Hmax/Dwidth	1.06 ± 0.34	0.97 ± 0.30	0.24	0.49	0.58
Hmax/Dlength	1.13 ± 0.42	0.99 ± 0.28	<0.01*	0.07	0.58
Hmax/Dmin	1.22 ± 0.41	1.08 ± 0.30	<0.01*	0.5	0.61
Hmax/Dmax	0.96 ± 0.31	0.88 ± 0.24	0.179	0.43	0.57
Bottleneck factor					
Dwidth/Nwidth	1.77 ± 0.91	1.45 ± 0.53	<0.001*	<0.001*	0.62
Dwidth/Nlength	1.57 ± 0.84	1.42 ± 0.59	1.06	0.11	0.55
Dwidth/Nmin	1.92 ± 1.01	1.59 ± 0.62	<0.001*	<0.001*	0.61
Dwidth/Nmax	1.43 ± 0.62	1.29 ± 0.46	0.28	0.15	0.57
Dlength/Nwidth	1.68 ± 0.90	1.42 ± 0.53	<0.01*	<0.01*	0.59
Dlength/Nlength	1.48 ± 0.79	1.37 ± 0.54	4.11	0.46	0.53
Dlength/Nmin	1.81 ± 0.95	1.55 ± 0.61	<0.05*	<0.01*	0.59
Dlength/Nmax	1.35 ± 0.66	1.25 ± 0.42	2.17	0.81	0.54
Dmin/Nwidth	1.52 ± 0.76	1.29 ± 0.43	<0.1*	<0.01*	0.59
Dmin/Nlength	1.34 ± 0.70	1.26 ± 0.50	4.78	0.51	0.53
Dmin/Nmin	1.64 ± 0.83	1.41 ± 0.53	<0.05*	<0.01*	0.59
Dmin/Nmax	1.23 ± 0.56	1.15 ± 0.36	2.13	0.76	0.54
Dmax/Nwidth	1.94 ± 0.98	1.59 ± 0.58	<0.001*	<0.001*	0.63
Dmax/Nlength	1.70 ± 0.88	1.54 ± 0.59	0.75	0.06	0.55
Dmax/Nmin	2.09 ± 1.06	1.73 ± 0.66	<0.001*	<0.001*	0.62
Dmax/Nmax	1.56 ± 0.68	1.40 ± 0.47	0.21	0.1	0.58

Values are presented as mean ± SD.
AUC, area under the curve; Hmax, aneurysm maximal height; Dwidth, dome width; Dlength, dome length; Dmax, dome maximal diameter; Dmin, dome minimal diameter; Nwidth, neck width; Nlength, neck length; Nmax, neck maximal diameter; Nmin, neck minimal diameter.
*Statistically significant.

Table 4. Interobserver Measurement Validation Using Intraclass Correlation Coefficient

Parameter	Mean ICC	95% CI
Hmax	0.83	0.58 to 0.93
Nwidth	0.71	0.26 to 0.88
Nlength	0.95	0.88 to 0.98
Nmin	0.82	0.56 to 0.93
Nmax	0.57	−0.08 to 0.83
Dwidth	0.79	0.47 to 0.97
Dlength	0.81	0.51 to 0.92
Dmin	0.83	0.57 to 0.93
Dmax	0.87	0.69 to 0.95

ICC, intraclass correlation coefficient; CI, confidence interval; Hmax, aneurysm maximal height; Nwidth, neck width; Nlength, neck length; Nmin, neck minimal diameter; Nmax, neck maximal diameter; Dwidth, dome width; Dlength, dome length; Dmin, dome minimal diameter; Dmax, dome maximal diameter.

In the literature, it is demonstrated that aneurysm Nwidth, as the size of the entrance to the aneurysm dome, is related to aneurysm hemodynamics.[12] Nmin and Nwidth may possibly provide information about narrow neck regions which may influence intra-aneurysmal flow velocity.[5] The intra-aneurysmal flow volume and velocity are associated with an event of aneurysm rupture, which has been previously demonstrated.[5,10,28] According to Ujiie et al.,[10] flow conditions in the aneurysm dome are highly dependent on the height-to-neck ratio (AR). Therefore, aneurysm neck size as a determinant for aneurysm rupture should be interpreted together with aneurysm height.[10] In aneurysms with a high AR, the flow conditions are related to injurious transformations in the aneurysm wall that lead to inflammation and local degeneration of the wall, which predispose to aneurysm rupture.[29]

AR as a predictor for aneurysm rupture has been reported in many studies, but the definite clinical significance of this parameter and the threshold value have not been yet established.[12,29] In the literature, there is still controversy and incoherence about the measurement method of the AR.[5,10,12-14] The most commonly cited definitions of AR are "aneurysm depth to aneurysm neck width," "dome to neck," "height to neck width," and "maximum perpendicular height-to-mean neck diameter."[10,13,17,18,30] In a previous study by Lauric et al.,[5] several definitions of AR were analyzed, and Hmax/Nmin was identified to be the best performer in determining rupture status (AUC, 0.75). Hmax/Nwidth as an independent predictor for SAH reported in our study is in line with the report of Lauric et al.[5] The authors emphasized the role of Hmax as an important component of AR and other complex parameters. On the other hand, our results indicate the substantial function of narrow neck regions parameters (Nwidth and Nmin) as the other element of AR. In the report of Lauric et al.,[5] the size of the neck, regardless of the definition, was not found to be a predictor for rupture; however, the use of Nmin, in contrast to Nmax, increased AR and BNF performance. Moreover, similar to our study, all complex parameters analyzed by Lauric et al.,[5] and defined with the use of Nmin, were statistically significant for rupture status discrimination. In our publication, the optimal threshold value for rupture prediction as 1.45 using Hmax/Nwidth is in line with previous reports.[5,7,9,31,32]

According to our results, aneurysm location with significantly higher rupture risk of anterior communicating artery aneurysms is also an independent predictor for SAH. Location of intracranial aneurysms at that anterior communicating artery and posterior communicating artery and posterior circulation aneurysms have been already acknowledged as risk factors for SAH in many previous retrospective and prospective reports.[3,4,21,33,34]

Limitations

The limitation of the study is its retrospective character and the lack of certainty that aneurysm size and geometry do not change after rupture. Additionally, there may be differences in volume rendering that influence on sizing methodology.[35] It also needs to be noted that measurement of simple anatomic parameters may not be adequate to characterize the complex geometry of an aneurysm.[36] It has been proven that despite the common maximum dimension or neck size, aneurysms may have remarkably dissimilar shape, which may be associated with intra-aneurysmal flow patterns and heterogeneous risk of rupture.[36]

CONCLUSIONS

Different definitions of aneurysm size and shape parameters affect various rupture risk determination. AR defined as Hmax/Nwidth, together with aneurysm location with significantly higher rupture risk of anterior communicating artery aneurysms, are independent predictors for SAH. To reliably compare results across reports, accurate descriptions of measurement parameters and standardization of aneurysm sizing methodology should be applied in clinical and scientific research studies.

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Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 2 November 2018; accepted 30 January 2019

Citation: World Neurosurg. (2019) 126:e157-e164. https://doi.org/10.1016/j.wneu.2019.01.283

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