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Enlargement of small, asymptomatic, unruptured intracranial aneurysms in patients with no history of subarachnoid hemorrhage: the different factors related to the growth of single and multiple aneurysms

Clinical article

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Object. This study was performed to investigate the risk factors related to the growth of small, asymptomatic, unruptured aneurysms in patients with no history of subarachnoid hemorrhage (SAH).

Methods. Between January 2005 and December 2010, a total of 508 patients in whom unruptured intracranial aneurysms were diagnosed at the University of California, Los Angeles medical center did not receive treatment to prevent rupture. Of these, 235 patients with no history of SAH who had asymptomatic, small, unruptured aneurysms (< 7 mm) were monitored with 3D CT angiography images. Follow-up images of the lesions were used to measure aneurysm size changes. Patient medical history, family history of SAH, aneurysm size, and location were studied to find the risk factors associated with small aneurysm growth.

Results. A total of 319 small aneurysms were included, with follow-up durations of 29.2 ± 20.6 months. Forty-two aneurysms increased in size during the follow-up; 5 aneurysms grew to become ≥ 7 mm within 38.2 ± 18.3 months. A trend of higher growth rates was found in single aneurysms than in multiple aneurysms ($p = 0.07$). A history of stroke was the only factor associated with single aneurysm growth ($p = 0.03$). The number of aneurysms ($p = 0.011$), number of aneurysms located within the posterior circulation ($p = 0.030$), and patient history of transient ischemic attack ($p = 0.044$) were related to multiple aneurysm growth.

Conclusions. Multiple small aneurysms are more likely to grow, and multiple aneurysms located in the posterior circulation may require additional attention. Although single aneurysms have a lower risk of growth, a trend of higher growth rates in single aneurysms was found.
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Key Words • **aneurysm growth** • **single aneurysm** • **multiple aneurysms** • **vascular disorders**

The prognosis of SAH remains poor despite various advancements in medical treatment, and 85% of SAH is caused by intracranial aneurysm rupture.[8] Because SAH is associated with a 40%–50% mortality rate, and approximately 20% of patients who survive have significant neurological impairment and disability, clinical management of UIAs to prevent rupture is an important issue.[7,23]

Because not all unruptured aneurysms will rupture, the risk presented by treatment and the risk of aneurysm rupture need to be carefully evaluated.[9,15] The reports from the ISUIA suggested that small (< 7 mm), asymptomatic, unruptured aneurysms in patients with no history of SAH should be managed conservatively.[27] Because clinical management of unruptured aneurysms is a complex and controversial issue, several studies have reported the risk of rupture in small unruptured aneurysms that were observed without treatment.[5,10,19,22]

Unlike small aneurysm rupture, information about the growth of small unruptured aneurysms is limited and

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Abbreviations used in this paper: ACA = anterior cerebral artery; AChA = anterior choroidal artery; ACoA = anterior communicating artery; BA = basilar artery; CTA = CT angiography; ICA = internal carotid artery; ICA-Ca = cavernous segment of ICA; ICA-Oph = ophthalmic segment of ICA; ISUIA = International Study of Unruptured Intracranial Aneurysms; MCA = middle cerebral artery; MRA = MR angiography; PCA = posterior cerebral artery; PCoA = posterior communicating artery; PICA = posterior inferior cerebellar artery; SAH = subarachnoid hemorrhage; SCA = superior cerebellar artery; TIA = transient ischemic attack; UCLA = University of California, Los Angeles; UIA = unruptured intracranial aneurysm; VA = vertebral artery.

heterogeneous due to limited follow-up data and differences in follow-up image quality.[2,3,7,11,20–22,24] Researchers have found that unruptured aneurysms enlarging in size may be a sign of aneurysmal instability and may indicate increased risk of rupture.[18,25,27] Therefore, studying the factors that relate to small aneurysm growth and may consequently change an aneurysm from low risk (< 7 mm) to higher risk (≥ 7 mm) can be valuable to the study of aneurysm natural history and clinical aneurysm management.

Based on the ISUIA suggestions for aneurysm management, in our center a group of small, asymptomatic, unruptured aneurysms in patients with no history of SAH were monitored with follow-up noninvasive imaging beginning in 2005. We performed a retrospective analysis of small unruptured aneurysms that were followed using high-resolution CTA, and sought to investigate the factors related to growth in this group of low-risk aneurysms. Patient demographic information (age, sex), medical history, aneurysm size, and aneurysm anatomical information were studied to find the factors associated with aneurysm growth.

Methods

Patient Population

The study was approved by the UCLA Institutional Review Board. The records of 1028 patients in whom intracranial aneurysms were diagnosed in the UCLA medical center between January 2005 and December 2010 were reviewed. A total of 508 patients who had small (< 7 mm), asymptomatic UIAs and no history of SAH did not receive aneurysm treatments to prevent rupture by either neurosurgical or endovascular intervention. Because of the low rupture risk associated with this group of aneurysms, 278 of the 508 patients were continuously followed using MRA or CTA neurovascular images in our center. A total of 230 patients did not participate in the follow-up imaging or elected to receive aneurysm follow-up at other imaging facilities. To ensure that the aneurysm image data were comparable in the analysis of aneurysm follow-up images, 235 patients in whom CTA follow-up images were obtained were selected consecutively. A total of 319 small, unruptured, saccular-shaped intracranial aneurysms that had been followed using serial CTA were analyzed. The end points of the follow-up were when the aneurysms were treated with either surgical clipping or endovascular coil placement, patients refused further follow-up, or failed to return for a follow-up visit. The complete follow-up periods were calculated from the date of initial diagnostic CTA, which identified the aneurysms to the date of the last follow-up scan.

Data Collection

Clinical data were collected through the electronic medical records and image database. Clinical information including demographics (age, sex) and medical history (history of TIA, stroke, hypertension, diabetes mellitus, coronary artery disease, previous or current cigarette smoking, excessive alcohol use, and family history of aneurysmal SAH in an immediate relative) was recorded.

Information on the number of aneurysms, characteristics of each aneurysm (location, size, and enlargement), and patient medical history were incorporated to find factors related to enlargement of the unruptured aneurysm. Aneurysm location was classified into ICA, ACA, MCA, and posterior circulation. Specific aneurysm locations including ICA-Ca, ICA-Oph, ICA-PCoA, ICA-AChA, ICA bifurcation, MCA, ACoA, distal ACA, VA, PICA, BA, SCA, and PCA were also compared to find the influence on aneurysm growth.

Aneurysm Analysis

A Sensation CT System (Siemens) was used in the clinical follow-up scans. The medical image visualization package Vitrea (Vital Images, Inc.) was applied for the postprocessing image reconstruction and aneurysm measurements. The CTA images were acquired with in-plane resolution of 0.35 mm × 0.35 mm (columns to rows were 512 × 512) and with a 0.75-mm slice thickness. The determinations of aneurysm size were based on the greatest dimensions of the aneurysm sacs on images. Although subvoxel measurements can be obtained by image visualization software, for reliable identification of the aneurysm enlargement, lesions with an overall change in size exceeding 0.75 mm (the minimum image resolution) during the follow-up were considered to have enlarged. Once the aneurysm was categorized as enlarged, the size changes on different follow-up scans were then recorded using the visualization package, which applied linear perturbation to obtain subvoxel dimensional changes.

Statistical Analysis

Multiple logistic regression analysis was performed using growth and nongrowth as the dependent outcomes. Independent factors were selected using a forward stepwise algorithm to determine the most parsimonious model. The Hosmer-Lemeshow statistic was calculated to test the goodness-of-fit of the model. A receiver operating characteristic analysis was then applied using the model, and the area under the curve was used as the performance measure. A 2-sample Student t-test was applied to compare the aneurysm growth rate in different groups. The IBM SPSS Statistics version 20 software was used for statistical analysis, and significance was assessed at 5%.

Results

Table 1 summarizes the patients' medical history and characteristics of the aneurysms included in this study. Additional information about detailed aneurysm size and location can be found in Table 2. During the average 29.2 months of follow-up (range 3–82 months), 42 aneurysms enlarged in size and 277 were unchanged. In the 42 aneurysms that showed growth during the follow-up (13.2% of the total aneurysms), 24 ± 17.5 months elapsed between the initial CTA scan and the scan that documented the enlargement. The total durations of follow-up for the growing and nongrowing aneurysms were 38.7 ± 20.5 months and 27.7 ± 20.2 months, respectively. There is no statistical difference in follow-up duration between the 2 groups ($p = 0.242$). It should be noted that when signs of aneurysm growth were detected the follow-up continued,

TABLE 1: Characteristics of 319 small, asymptomatic UIAs*

Characteristic	Total	Aneurysm Growth	
		Yes	No
aneurysm-specific information			
no. of aneurysms	319	42	277
mean FU in mos	29.2 ± 20.6	38.7 ± 20.5	27.7 ± 20.2
mean initial size in mm	3.6 ± 1.4	3.7 ± 1.6	3.6 ± 1.3
no. in ant circulation	296	36	260
ICA	180	18	162
MCA	60	12	48
ACA	56	6	50
no. in pst circulation	23	6	17
VA + PICA	5	2	3
BA + SCA	16	3	13
PCA	2	1	1
patient-specific information			
no. of patients	235	34	201
mean age in yrs	62.0 ± 13.6	63.4 ± 13.1	61.8 ± 13.7
no. of women	200	30	170
no. of men	35	4	31
no. w/ single aneurysm	135	11	124
no. w/ multiple aneurysms	100	23	77
no. w/ medical history available	223	33	190
history of TIA	15	4	11
history of stroke	10	4	6
hypertension	96	1	79
diabetes mellitus	23	6	17
coronary artery disease	22	4	18
previous or current cigarette smoking	61	8	53
excessive alcohol use	6	0	6
family history of intracranial aneurysms	9	1	8

* The mean is expressed ± SD throughout the tables. Abbreviations: ant = anterior; FU = follow-up; pst = posterior.

whereas when small aneurysms did not show growth during the follow-up, many patients elected not to continue the follow-up imaging. Therefore, even though the total follow-up duration for aneurysms that showed growth was longer (38.7 ± 20.5 months), the growth was found at an average of 24 months, which was shorter than the average follow-up time for nongrowing aneurysms (27.7 months). Due to the lack of further follow-up information for nongrowing aneurysms, it is unknown if this group of aneurysms will eventually grow. On the other hand, for the small aneurysms that showed growth, 12 (29%), 25 (60%), 30 (71%), and 35 (83%) of these aneurysms were found enlarged within 12, 24, 36, and 48 months, respectively. For aneurysms located in the ICA, MCA, ACA, and posterior circulation, 10%, 20%, 11%, and 26% of aneurysms enlarged, respectively. Logistic regression analysis shows that the number of aneurysms was significantly associated with growth of small unruptured aneurysms ($p < 0.001$).

Among the aneurysms that showed growth, 20 aneurysms had growth < 1.0 mm, 15 showed growth between 1.0 and 1.5 mm, and 7 aneurysms showed growth > 1.5 mm. There were 5 aneurysms (in 5 patients) that grew to become > 7 mm (Table 3). All of these aneurysms had an initial size > 6 mm. The single aneurysms had greater size increases than multiple ones. The follow-up CTA scans were terminated in 2 of the 5 patients because these patients wished to have operations to prevent aneurysm rupture. Both aneurysms were treated with endovascular intervention.

Tables 4 and 5 compare the aneurysm size changes during the follow-up and the aneurysm growth rate in patients; the data are expressed as the mean ± SD. Based on the Student t-test, a trend of higher growth rate was found in single aneurysms (0.88 ± 0.69 mm/yr) compared with the rate in multiple aneurysms (0.58 ± 0.37 mm/yr) ($p = 0.07$).

Analysis of the risk factors related to aneurysm growth in single and multiple aneurysm groups is shown in Tables 6 and 7, respectively. Of the single aneurysms, 8.1% showed growth during the follow-up, as did 16.8% of the multiple aneurysms. A history of stroke was the

TABLE 2: Detailed size and location information for 319 small, asymptomatic UIAs

Characteristic	Total	No. w/ Aneurysm Growth	
		Yes	No
initial size in mm			
1.0–1.9	32	7	25
2.0–2.9	89	10	79
3.0–3.9	86	10	76
4.0–4.9	51	5	46
5.0–5.9	35	4	31
6.0–6.9	26	6	20
location of aneurysms			
ICA-Ca	38	3	35
ICA-OphA	97	7	90
ICA-PCoA	32	6	26
ICA-AChA	9	2	7
ICA bifurcation	4	0	4
MCA	60	12	48
ACoA	48	5	43
distal ACA	8	1	7
VA + PICA	5	2	3
BA + SCA	16	3	13
PCA	2	1	1

only statistically significant factor found to associate with the growth of single aneurysms ($p = 0.03$), with predicted probability of 0.578 (receiver operating characteristic–area under curve) ($p = 0.395$; 95% CI 0.34–0.77). The growth of a multiple aneurysm is directly related to the total number of lesions that the patient had ($p = 0.011$). Multiple aneurysms located in the posterior circulation and multiple aneurysms in patients with a history of TIA tended to grow ($p = 0.030$ and $p = 0.044$, respectively). Combined factors of the number of aneurysms, posterior circulation, and history of TIA were able to predict growth of multiple aneurysms with predicted probability of 0.67 ($p = 0.003$; 95% CI 0.556–0.784).

Discussion

Studies focusing on the follow-up of small, asymptomatic, unruptured aneurysms with no history of SAH are limited. Because aneurysm growth can be erratic and can relate to rupture, identifying factors associated with the progression of size changes in this low-risk group is valuable for clinical aneurysm management and for assisting the evaluation of increasing risk while follow-up continues.[2] Related research based on aneurysm follow-up has suggested risk factors related to rupture and growth in a mixture of patients who had a history of SAH.[3,10,21,22,26]

In a study of the risk of rupture of small aneurysms (< 5 mm) in the Japanese population, Sonobe et al.[22] also reported risk factors related to aneurysm enlargement. With combinations of asymptomatic and symptomatic aneurysms and lesions with history of SAH in the study population, they found that the independent risk factors for aneurysm enlargement were female sex, aneurysms > 4 mm, multiplicity (> 1 aneurysm), and current smoking. Our finding is in agreement with Sonobe et al.'s report. Based on 319 small, asymptomatic, unruptured aneurysms with no history of SAH (ISUIA Group 1), we also found that the number of aneurysms was a significant factor related to growth. Although other factors such as female sex and smoking status were not significantly related to aneurysm growth in our study, this may be due to differences in inclusion criteria when combinations of patients with different risk factors are studied.

Unlike previous studies that suggested that the aneurysm's initial size is a significant factor related to its growth, the initial size was not significantly related to growth in our study (Table 1).[2,16,20] Our results showed that 13.2% of aneurysms grew, for sizes ranging from 1 mm to 6.9 mm. This discrepancy may be due to the fact that studies reporting initial size as a risk factor related to growth were based on a wide range of aneurysm sizes (2–15 mm in Phan et al.;[20] 2–20 mm in Matsubara et al.;[16] 2–18.4 mm in Burns et al.[2]), whereas the current study focused on the growth of small aneurysms. As reported by Allcock and Canham,[1] analyzing the growth rate with respect to initial size in aneurysms < 7 mm, 7–15 mm, and > 15 mm showed different growth rates in each group. Our hypothesis is that initial size may be a more important indicator for growth of aneurysms ≥ 7 mm.

Our results showed that 1) in small aneurysms (ISUIA Group 1), growth is related to the number of aneurysms; 2) the risk factors related to single and multiple aneurysm growth are different; and 3) although aneurysm growth is positively related to the total number of lesions, single aneurysms tend to have a higher growth rate (in millimeters per year) than multiple aneurysms. These findings suggest that although single aneurysms are less likely to grow compared with multiple aneurysms, more frequent follow-up imaging may be beneficial to examine morpho-

TABLE 3: Characteristics of 5 small aneurysms that grew larger than 7 mm

Case No.	Sex, Age (yrs)	Single/Multiple	No. of Aneurysms	Initial Size (mm)	Enlargement (mm)	FU (mos)	Location	Treatment
1	F, 70	single	1	6.3	1.8	23	PCoA	none
2	F, 75	single	1	6.9	2.2	59	ACoA	none
3	F, 73	multiple	2	6.3	0.9	22	MCA	none
4	F, 64	multiple	2	6.8	1.0	57	BA	coils
5	F, 79	multiple	2	6.9	1.5	30	VA	coils

TABLE 4: Growth of 42 small, asymptomatic UIAs

Characteristic	No. of Aneurysms*	Mean Size Change During FU (mm)	Mean Growth Rate (mm/yr)
sex			
female	36	1.14 ± 0.41	0.60 ± 0.47
male	6	0.93 ± 0.16	1.00 ± 0.46
history of TIA			
yes	4	1.00 ± 0.27	0.66 ± 0.37
no	37	1.14 ± 0.40	0.67 ± 0.50
history of stroke			
yes	4	1.25 ± 0.65	0.44 ± 0.07
no	37	1.11 ± 0.36	0.69 ± 0.51
hypertension			
yes	21	1.07 ± 0.36	0.56 ± 0.26
no	20	1.18 ± 0.42	0.79 ± 0.63
diabetes mellitus			
yes	6	0.92 ± 0.24	0.50 ± 0.32
no	35	1.16 ± 0.40	0.70 ± 0.51
coronary artery disease			
yes	4	0.98 ± 0.29	0.49 ± 0.40
no	37	1.14 ± 0.40	0.69 ± 0.50
previous or current cigarette smoking			
yes	8	0.98 ± 0.15	0.82 ± 0.83
no	33	1.16 ± 0.42	0.63 ± 0.37
family history of intracranial aneurysms			
yes	1	1.2	0.80
no	40	1.12 ± 0.39	0.66 ± 0.49
no. of aneurysms			
single	11	1.20 ± 0.50	0.88 ± 0.69†
multiple	31	1.11 ± 0.39	0.58 ± 0.37†
location of aneurysm			
ant circulation	36	1.09 ± 0.38	0.70 ± 0.50
pst circulation	6	1.23 ± 0.44	0.42 ± 0.19

* Results in patients with growing aneurysms (42 aneurysms in 34 patients). Medical history was available for 41 of 42 growing aneurysms; for 1 patient with a growing single aneurysm, the medical history was not available.
† Significant at $p = 0.07$ according to the Student t-test.

logical changes. Based on their average growth rate of 0.88 mm/yr, for single 6- to 7-mm aneurysms, a 10-month follow-up may help to monitor the size changes, because higher rupture rates have been reported in aneurysms 7–9 mm in size.[27]

To the best of our knowledge, a detailed study about the risk factors in the growth of single and multiple aneurysms has not yet been reported. The underlying mechanism of the formation, growth, and rupture of single and multiple aneurysms is complicated. Juvela[11] found that patients with hypertension tend to have more aneurysms. Research investigating the growth and formation of aneurysms in 50 patients with multiple lesions has shown a low rate of multiple aneurysm growth.[6] Trends of different growth rates in single and multiple aneurysms have also been reported.[2,11,16,22] However, the rupture risk of single and multiple aneurysms has not been shown to be different in most studies.[9,12,13,19,24,25,27] Whether the 2 groups of aneurysms share the same cause of formation, growth, and rupture is unclear. Although multiplicity is not considered a risk factor related to aneurysm rupture, our results raise the possibility that different management strategies may be needed in the follow-up of single and multiple small aneurysms.

In our study we found that single aneurysm growth is related to a patient's history of stroke and that multiple aneurysm growth is related to a history of TIA, location in the posterior circulation, and the number of aneurysms. These results suggest that for small, asymptomatic, unruptured aneurysms in patients with no history of SAH, for both single and multiple aneurysms the lesions' growth may relate to a patient's history of cerebrovascular disease. Because few studies have analyzed the relationship between cerebrovascular disease and aneurysm growth

TABLE 5: Detailed size and location information for growth of 42 small, asymptomatic UIAs

Characteristic	No. of Aneurysms	Average Size Change During FU (mm)	Average Growth Rate (mm/yr)
initial size in mm			
1.0–1.9	7	1.14 ± 0.48	0.51 ± 0.30
2.0–2.9	10	1.10 ± 0.37	0.59 ± 0.50
3.0–3.9	10	1.02 ± 0.31	0.69 ± 0.33
4.0–4.9	5	1.14 ± 0.33	0.83 ± 1.01
5.0–5.9	4	0.93 ± 0.10	0.95 ± 0.53
6.0–6.9	6	1.37 ± 0.56	0.53 ± 0.24
location of aneurysms			
ant circulation	36	1.09 ± 0.38	0.70 ± 0.50
ICA	18	1.18 ± 0.42	0.56 ± 0.31
ICA-Ca	3	1.03 ± 0.21	0.49 ± 0.18
ICA-OphA	7	1.04 ± 0.35	0.50 ± 0.34
ICA-PCoA	6	1.50 ± 0.50	0.65 ± 0.32
ICA-AChA	2	0.90 ± 0.00	0.58 ± 0.45
MCA	12	0.92 ± 0.11	0.60 ± 0.37
ACA	6	1.20 ± 0.52	1.31 ± 0.81
ACoA	5	1.22 ± 0.58	1.05 ± 0.54
distal ACA	1	1.10	2.20
pst circulation	6	1.23 ± 0.44	0.42 ± 0.19
VA + PICA	2	1.20 ± 0.42	0.39 ± 0.30
BA + SCA	3	1.30 ± 0.61	0.40 ± 0.20
PCA	1	1.10	0.53

and rupture, further study is needed to help understand the relationship between other cerebrovascular diseases and brain aneurysms.[11,17]

Small aneurysms located in the posterior circulation have been reported to associate with higher risk of rupture.[19,27] Our study also showed that aneurysm location in the posterior circulation was a predictive factor for multiple aneurysm growth. Therefore, considering the risk of growth and rupture, multiple aneurysms located in the posterior circulation may require additional attention during follow-up. It should be noted that, although none of the single aneurysms located in the posterior circulation showed growth, this may result from the patient selection in our center, because there were only 9 single aneurysms

TABLE 6: Risk factors and growth of 135 single, small, asymptomatic UIAs

Characteristic	No. w/ Aneurysm Growth (%)		p Value
	Yes	No	
no. of patients	11	124	
history of TIA	0 (0)	8 (6.5)	0.430
history of stroke	2 (18.2)	3 (2.4)	0.030*
hypertension	4 (36.4)	45 (36.3)	0.076
diabetes mellitus	2 (18.2)	10 (8.1)	0.312
coronary artery disease	0 (0)	7 (5.6)	0.450
previous or current cigarette smoking	2 (18.2)	37 (29.8)	0.557
excessive alcohol use	0 (0)	4 (3.2)	0.573
family history of intracranial aneurysms	1 (9.1)	4 (3.2)	0.274
mean FU in mos	31.6 ± 22.9	26.9 ± 20.7	0.945
mean initial size in mm	4.2 ± 1.4	3.6 ± 1.3	0.205
ant circulation	11 (100)	115 (92.7)	0.348
pst circulation	0 (0)	9 (7.3)	0.527

* $p < 0.05$.

TABLE 7: Risk factors and growth of 184 multiple, small, asymptomatic UIAs

Characteristic	No. w/ Aneurysm Growth (%) Yes	No	p Value
no. of patients	23	77	
history of TIA	4 (17.4)	3 (3.9)	0.044*
history of stroke	2 (8.7)	3 (3.9)	0.580
hypertension	13 (56.5)	34 (44.2)	0.264
diabetes mellitus	4 (17.4)	7 (9.1)	0.478
coronary artery disease	4 (17.4)	11 (14.3)	0.795
previous or current cigarette smoking	6 (26.1)	16 (20.8)	0.796
excessive alcohol use	0 (0)	2 (2.6)	0.439
family history of intracranial aneurysms	0 (0)	4 (5.2)	0.340
mean FU in mos	41.2 ± 19.3	29.9 ± 20.3	0.081
mean initial size in mm	3.5 ± 1.7	3.6 ± 1.4	0.929
ant circulation	25 (80.6)	145 (94.8)	0.333
pst circulation	6 (19.4)	8 (5.2)	0.030*
no. of aneurysms			0.011*
2	18 (58.1)	96 (62.7)	
3	4 (12.9)	29 (18.9)	
4	3 (9.7)	27 (17.6)	
≥5	6 (19.4)	1 (0.7)	
total	31	153	

* $p < 0.05$.

(of a total 135 single lesions) in the posterior circulation that were followed. Further long-term follow-up study of single aneurysms will help us understand whether location is also a factor related to their growth.

Limitations of the Study

This is a single-center, retrospective study. The purpose of the study was to investigate the growth of small aneurysms during follow-up. One of the limitations of the study is the population bias introduced by the fact that more than 45% of patients (230 of 508) in whom small, asymptomatic UIAs were diagnosed had no history of SAH and elected not to participate in the follow-up imaging. Furthermore, due to the inclusion criteria, none of the ruptured small aneurysms had the intermediate data (to indicate growth prior to rupture) necessary to be included in this study. To further understand small aneurysm growth, a multicenter study with long-term follow-up data is important to minimize the bias due to patient selection. Moreover, the current findings may only provide information to understand the growth in asymptomatic small aneurysms with no history of SAH. Different factors may be associated with aneurysm growth in patients with a history of SAH.

Studies have reported that multiplicity relates to aneurysm growth; however, analysis comparing the growth of single and multiple small aneurysms was previously not available.[2,11,16,22] In our study we also found that small aneurysm growth is related to multiplicity ($p < 0.001$). Therefore, we further investigated whether there are differences in aneurysm growth in single and multiple aneurysms. Because of the limitations of cases and patient population, this paper reported the trend of small aneurysm growth based on single-center experiences. Further study with more cases is needed to understand the factors associated with growth in single and multiple aneurysms.

In studies of aneurysm growth, one of the major challenges is defining a reliably measured threshold that determines growth. In the past, different size change criteria have been used in studies of aneurysm growth ranging from 0.5 mm to 2 mm.[3,14,20,22,26] So far there are no guidelines to help define growth and limited information about how much a small aneurysm can grow in 6 years (our study period). Although size change > 0.5 mm has been implemented to define small aneurysm growth in CTA-based studies, we defined growth as a change in size larger than the dimensions of the image resolution (0.75 mm).[3,26] It should be noted that either 1 mm or 2 mm can also be used to classify growth; however, the larger growth definition requires a larger percentage size change. For example, using a 1-mm size change to define growth, for 3.6-mm aneurysms (the average aneurysm size in our study population) the aneurysm needs to grow more than 27% to be considered. Further study investigating what change in size is meaningful will be important to help research of the growth of small aneurysms.

Limited by aneurysm imaging methods and available cases, studies of aneurysm growth have used different standards to define enlargement.[2,21] Because the scale of aneurysm geometrical changes can be lower than the imaging resolution, high-resolution imaging techniques can greatly improve how small a size change can be detected.[3] Because 3D CTA has been the standard technique for clinical follow-up in our center, to ensure that the image data are consistent and comparable, we have excluded aneurysm cases that were not followed using CTA. In the future, better diagnostic imaging methods such as contrast-enhanced MRI could be helpful to include more aneurysm cases and monitor detailed aneurysm changes.[4]

Conclusions

We found different risk factors related to the growth of single and multiple aneurysms classified in ISUIA Group 1. Single aneurysms tend to have higher growth rate per year compared with multiple aneurysms. Multiple aneurysms located in the posterior circulation may require additional attention during the imaging follow-up.

Disclosure

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