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Original Article

Clinical and Morphological Characteristics of Ruptured Small (<5 mm) Posterior Communicating Artery Aneurysms

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Abstract

Context: Small intracranial aneurysms (IAs) are considered to have a low risk of rupture; however, in clinical practice, we often encounter patients with subarachnoid hemorrhage (SAH) due to rupture of small IAs. **Aims:** This study aims to clarify the clinical and morphological characteristics of ruptured small IA, focusing on posterior communicating artery (PCoA) aneurysms as a prone site. **Settings and Design:** We retrospectively reviewed 102 consecutive patients with SAH due to ruptured PCoA aneurysm who underwent microsurgical or endovascular aneurysm repair between April 2013 and March 2018. **Subjects and Methods:** All PCoA aneurysms were diagnosed using three-dimensional rotation angiography or three-dimensional computed tomography angiography. Information regarding the following clinical characteristics was collected: age, sex, past medical history, current smoking, antithrombotic therapy, multiplicity, hydrocephalus, intracerebral hemorrhage, intraventricular hemorrhage, and World Federation of Neurosurgical Societies (WFNS) Grade on admission. **Statistical Analysis Used:** We analyzed factors of ruptured small IA, focusing on PCoA aneurysms using univariate and multivariate regression analyses. **Results:** Univariate and multivariate analyses revealed that low aspect ratio (AR) (odds ratio [OR] = 0.33, $P = 0.01$) and nonfetal type of PCoA (OR = 0.31, $P = 0.02$) might be independent characteristics of ruptured small PCoA aneurysms. However, age, sex, past medical history, WFNS grade, and treatment outcome were not different between the small and nonsmall PCoA aneurysms. The aneurysm size was not associated to the selection of treatment, proportion of complications, and treatment outcome. **Conclusions:** In cases of ruptured PCoA aneurysms, low AR and nonfetal type of PCoA might be associated with rupture of small aneurysms.

Keywords: *Aspect ratio, nonfetal type, posterior communicating artery, small intracranial aneurysm, subarachnoid hemorrhage*

Introduction

Intracranial aneurysm (IA) is a prevalent vascular disorder affecting 3%–8% of adults and could lead to subarachnoid hemorrhage (SAH).[1] Although the International Study of Unruptured Intracranial Aneurysms (ISUIA) study gives the impression that a small IA (SIA) has a low risk of rupture,[2] recent studies have shown that SIA has a high rate of rupture.[3-6] Therefore, knowing the characteristics of ruptured SIA is important for the management of patients with SIA. This study aims to clarify the clinical and image-based morphological characteristics of ruptured SIA, especially focusing on ruptured small posterior communicating artery (PCoA) aneurysms.

Subjects and Methods

Study population and data collection

We retrospectively reviewed 112 consecutive patients with SAH due to ruptured PCoA aneurysm diagnosed at our institution between April 2013 and March 2018. All the PCoA aneurysms were diagnosed and several parameters were measured using three-dimensional rotation angiography (3DRA) or three-dimensional computed tomography (CT) angiography (3DCTA). Two neurosurgeons were in charge of measuring several parameters and collecting data. We defined small aneurysms as under 5 mm in size according to the previous Japanese study.[7] Ten patients were excluded because their angiographical findings were poor due

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to extremely high intracranial pressure and they did not reach the treatment phase after diagnosis. Finally, this study included 102 PCoA aneurysms that were treated using endovascular coiling or microsurgical clipping. Out of the 102 PCoA aneurysms, 33 were small and 69 were nonsmall in size on 3DCTA or 3DRA performed within 3 h after presenting to our institution. The clinical characteristics collected were as follows: age, sex, past medical history (hypertension, diabetes mellitus, and hyperlipidemia), current smoking, antithrombotic therapy, multiplicity, hydrocephalus, intracerebral hemorrhage (ICH), intraventricular hemorrhage, and World Federation of Neurosurgical Societies (WFNS) Grade on admission. This study was approved by our Institutional Review Board (19-012), and individual patient consent was not required as this was a retrospective study.

Radiological findings and morphological calculations

3DCTA or 3DRA are routinely performed in all patients in whom conventional CT confirms the presence of SAH. We measured the diameter of the origin of the internal carotid artery (ICA) and the proximal ICA–PCoA bifurcation, aneurysm size, and aspect ratio (AR). The size of the aneurysm dome was defined as the maximum diameter of the aneurysm dome and the dome height as the longest dimension from the neck to the dome tip. The AR was calculated by dividing the height of the dome by the width of the neck. A fetal type of PCoA was defined as a PCoA that has a caliber equal to or larger than the P1 segment of the posterior cerebral artery and is associated with atrophic P1 segments. Dome angle was defined as the angle between the inflow from the center of the neck to the tip of the dome and the major axis of the aneurysm; they were classified as lateral and posterior projections, respectively.

Statistical analysis

Quantitative variables were expressed as the median (interquartile range) or number of patients (%) as appropriate. The Chi-square test or Fisher's exact test was performed to evaluate covariates for binary categorical dependent variables as appropriate. The normality of the data was evaluated using the Shapiro–Wilk test. Nonnormal variables were compared using the Mann–Whitney U test. Parameters ($P < 0.10$) that were found to be significant in univariate analysis were further analyzed using multivariate logistic regression to identify those that remained significant when describing all relevant parameters. Differences were considered significant at $P < 0.05$. The commercially available software SPSS version 24 (IBM Corp, Armonk, New York, USA) was used for all the statistical analyses.

Results

Patient characteristics

Table 1 shows the baseline characteristics of 102 patients with ruptured PCoA aneurysm. Out of 102 patients,

Table 1: Baseline characteristics of 102 patients with ruptured posterior communicating artery aneurysms

Category	Total cases (*n*=102), *n* (%)	Size of ruptured PCoA aneurysms (mm)		*P*
		<5 (*n*=33), *n* (%)	≥5 (*n*=69), *n* (%)	
Clinical characteristics				
Age (years)±SD	67.4±2.2	64.4±3.1	68.9±1.7	
<50	19 (18.6)	9 (27.3)	10 (14.5)	0.12
≥50	83 (81.4)	24 (72.7)	59 (85.5)	
Male	13 (12.7)	4 (12.1)	9 (13.0)	0.58
Female	89 (87.3)	29 (87.9)	60 (87.0)	
Hypertension	50 (49)	12 (36.4)	38 (55.1)	0.72
Diabetes mellitus	12 (11.8)	2 (6.1)	10 (14.5)	0.18
Hyperlipidemia	22 (21.6)	9 (27.3)	13 (18.8)	0.33
Current smoking	14 (13.7)	4 (12.1)	10 (14.5)	0.41
Antithrombotic therapy	10 (9.8)	6 (18.2)	4 (5.8)	0.06
Multiplicity	29 (28.4)	11 (33.3)	18 (26.1)	0.45
Hydrocephalus on admission	31 (30.4)	12 (36.4)	19 (27.5)	0.37
ICH or IVH on admission	31 (30.4)	7 (21.2)	24 (34.8)	0.35
WFNS I-III	67 (65.7)	26 (78.8)	41 (59.4)	0.12
WFNS IV-V	35 (34.3)	7 (21.2)	28 (40.6)	
Morphological characteristics				
Aspect ratio±SD	1.58±0.10	1.38±0.09	1.68±0.10	0.01
Bleb formation	59 (57.8)	14 (42.4)	45 (65.2)	0.03
Fetal type	43 (42.2)	9 (27.3)	34 (50.7)	0.04
Lateral projection	44 (43.1)	17 (51.5)	27 (39.1)	0.24
Posterior projection	58 (56.9)	16 (48.5)	42 (60.9)	

PCoA-Posterior communicating artery; SD-Standard deviation; ICH-Intracerebral hemorrhage; IVH-Intraventricular hemorrhage; WFNS-World Federation of Neurosurgical Societies

small and nonsmall size aneurysms were observed in 33 (32.4%) and 69 (67.6%) patients, respectively. Antithrombotic therapy before SAH (P = 0.06), low AR (P = 0.01), aneurysm bleb formation (P = 0.029), and nonfetal type of PCoA (P = 0.04) were significantly associated with ruptured small PCoA aneurysm. However, age (P = 0.12), sex (P = 0.58), past medical history, current smoking (P = 0.41), WFNS grade on admission (P = 0.12), treatment outcome, multiplicity (P = 0.45), and dome angle (P = 0.24) were not significantly different between the small and nonsmall PCoA aneurysms.

Specific characteristic of ruptured small posterior communicating artery aneurysms

Table 2 shows the multivariate analysis using variables that were marginally or significantly associated with each independent characteristic of ruptured small PCoA aneurysms. Low AR (odds ratio [OR], 0.33; 95% confidence interval [CI], 0.14–0.78; P = 0.011) and nonfetal type of PCoA (OR, 0.31; 95% CI, 0.12–0.82; P = 0.019) remained significant.

The treatment methods and outcome

The treatment modalities, complications, and outcomes of the 102 patients with ruptured PCoA aneurysms are shown in Table 3. Overall, 53 (52%) underwent clipping and 49 (48%) underwent coiling. Among the ruptured small PCoA aneurysms, 13 (39.4%) underwent clipping and 20 (60.6%) underwent coiling; there was a tendency to perform coiling for small-sized aneurysms at our institution; however, this trend was not significant (P < 0.079). One patient (3%) had cerebral infarction in the PCoA territory, 3 (9.1%) had symptomatic vasospasm, and 4 (12.1%) developed shunt-dependent hydrocephalus. None of the factors showed any significant difference with regard to complications between the small and nonsmall size groups. In ruptured small PCoA aneurysms, modified Rankin Scale (mRS) at discharge was from 0 to 2 in 20 (60.6%) cases.

Table 2: Independent characteristics of ruptured small (<5 mm) posterior communicating artery aneurysms

Characteristic	OR (95% CI)	*P*
Antithrombotic therapy	3.15 (0.71-14.0)	0.13
Aspect ratio	0.33 (0.14-0.78)	0.01
Bleb formation	0.43 (0.17-1.06)	0.06
Fetal type	0.31 (0.12-0.82)	0.02

PCoA-Posterior communicating artery; CI-Confidence interval; OR-Odds ratio

Discussion

As the availability of modern imaging technology increases, unruptured SIAs are more likely to be detected. Although the ISUIA study gives the impression that SIAs have a low risk of rupture, recent studies show that SIAs have a high rate of rupture.[2-6,8] Our study supports this notion; 32.4% of ruptured PCoA aneurysms were SIAs in this study. Clinical decision-making for unruptured SIAs is still difficult;[9,10] however, understanding the clinical and morphological characteristics of ruptured SIA can be of great utility. There have been many reports on the risk factors of rupture of IAs. However, the pathogenesis of formation and rupture of aneurysm are multifactorial, and most previous studies have not been location specific. In fact, the proportion of SIAs among all IAs and their risk of rupture varies in different locations.[8,11] Accordingly, the anatomical conditions, vessel diameter, and blood flow pattern differ depending on the location; thus, examining the risk of rupture at different locations with similar criteria is not ideal and location-specific studies may be more likely to achieve accurate results. The Natural Course of Unruptured Cerebral Aneurysms in a Japanese Cohort (UCAS Japan) showed that a PCoA aneurysm is more likely to rupture,[12] and thus, we focused on ruptured PCoA aneurysms in this study.

The AR reflects the depth-to-neck ratio, and most studies agree that a higher AR correlates with a higher risk of rupture.[13,14] A commonly used AR threshold value is 1.6, above which the risk significantly increases.[8] Qiu

Table 3: Treatment method and outcome in 102 patients with ruptured posterior communicating artery aneurysms

Category	Total cases (*n*=102), *n* (%)	Size of ruptured PCoA aneurysms (mm)		*P*
		<5 (*n*=33), *n* (%)	≥5 (*n*=69), *n* (%)	
Treatment method				
Clip	53 (52.0)	13 (39.4)	40 (58.0)	0.08
Coil	49 (48.0)	20 (60.6)	29 (42.0)	
Outcome				
PCoA territory infarction	11 (10.8)	1 (3.0)	10 (14.5)	0.07
Symptomatic vasospasm	15 (14.7)	3 (9.1)	12 (17.4)	0.21
Shunt-dependent hydrocephalus	15 (14.7)	4 (12.1)	11 (15.9)	0.43
Other complication	15 (14.7)	4 (12.1)	11 (15.9)	0.43
mRS 0-2	58 (56.9)	20 (60.6)	38 (55.1)	0.61
mRS 3-6	44 (43.1)	13 (39.4)	31 (44.9)	

PCoA-Posterior communicating artery; mRS-Modified Rankin Scale

et al. reported that the smaller the neck, the slower the flow, which is called the low flow theory.[15,16] Localized stagnation of blood flow in an aneurysm leads to endothelial dysfunction, which results in the destruction of endothelial cells; this is an important cause of IA rupture.[17-19] Thus, a higher AR seems to reflect a lower intra-aneurysmal blood flow and subsequently a higher risk of rupture, and the same applies to SIA.[14,20]

In this study, the AR threshold value of nonsmall aneurysms was 1.58 comparable to that in previous studies, whereas the AR threshold value of SIA was 1.38. The majority of SIAs in our series had small depth diameters and AR was relatively low compared to that of nonsmall size aneurysms. Ujiie *et al*. also reported that aneurysm size and AR are positively correlated.[21] As discussed earlier, the low flow theory is highly relevant to aneurysm rupture; however, our study demonstrated that low AR may be associated with rupture of SIA, and this was inconsistent with this theory. This discrepancy may be attributable to the nature of SIA itself characterized by a small depth and low AR. Otherwise, the low flow theory may simply not be applicable to SIA rupture.

The fetal type of PCoA was detected in 42% of patients in this study similar to that in previous studies.[13] The vessel diameter of PCoA is more likely to change a hemodynamic pattern and be involved in the development of an aneurysm.[22,23] However, the relationship between a fetal type of PCoA and risk of rupture is poorly documented. It is often argued that the fetal type is prone to IA formation and is likely to cause rupture risk;[20,24] this study showed that with respect to ruptured SIAs, the nonfetal type of PCoA was associated with rupture. Cebral *et al*. reported that ruptured IAs were more likely to have disturbed flow patterns, small impingement regions, and fluid jets in terms of hemodynamic characteristics.[25] Although there are many theories about the hemodynamic pattern in ruptured IA, it is generally thought that low wall shear stress (WSS) occurs in the IA and induces rupture in large IA.[26,27] In terms of size ratio (SR), it has been reported from experiments that increasing the value causes low WSS in the aneurysm and further increases the area of low WSS on the IA inner wall; moreover, jet flow causes focused flow impingement zones and complex flow patterns, which may be a major cause of rupture.[22,28]

In general, SR naturally increases when the side branch diameter decreases, like that seen in nonfetal PCoAs; moreover, the flow resistance in the side branch increases and fluid jet may be produced due to the high flow resistance. Certainly, PCoA aneurysms have complicated inflow conditions, and the computational fluid dynamics (CFD) results for sidewall IAs presented in other studies may not fully reflect the complex flow in all PCoA aneurysms.[22,26-28] This theory may be one of the reasons why nonfetal type PCoA was associated with SIA rupture in this study. Up to now, there have been no studies examining the characteristics of ruptured SIA which have been limited in location to PCoA aneurysm. Further analysis using CFD is needed to clarify the relationship between SIA rupture and nonfetal PCoA.

We compared the treatment modalities, complications, and outcomes between the small and nonsmall size aneurysms. Although no significant differences were recognized, SIAs were mainly treated using coil embolization in this study. Intraoperative asymptomatic cerebral infarction due to coil embolization was the main complication in our series. However, for SIAs, the treatment was often performed using simple techniques with a significantly low risk of thrombus formation and intraoperative cerebral infarctions were scarcely noted. Almost all of the radiographical complications were asymptomatic, and the aneurysm size was not associated with the development of hydrocephalus, vasospasm, and mRS at discharge.

Several limitations of this study must be mentioned. First, this study did not compare unruptured SIA with ruptured IA and did not evaluate the risk factors of ruptured and unruptured aneurysms to aid therapeutic intervention. Second, the study was conducted retrospectively at a single institution and the sample size was too small to draw definite conclusions on morphological and clinical characteristics, possibly leading to selection bias and wide confidence intervals. Moreover, although IA hemodynamic patterns have also been reported as important factors for aneurysm growth and rupture,[23] CFD evaluations were not conducted in this study.

Conclusions

Low AR and nonfetal type of PCoA might be significant factors and characteristics of ruptured small PCoA aneurysms. These factors may also have important implications in clinical practice. Focusing on identifying the clinical and morphological characteristics associated with ruptured small PCoA aneurysms might provide clinical guidance to further distinguish high-risk patients and develop the most appropriate treatment strategy for PCoA aneurysms.

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Conflicts of interest

There are no conflicts of interest.

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