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ORIGINAL ARTICLE - VASCULAR

CTA analysis and assessment of morphological factors related to rupture in 413 posterior communicating artery aneurysms

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Abstract Posterior communicating artery (PcomA) aneurysms are frequently encountered, but there are few publications on their morphology. A growing number of aneurysms are incidental findings, which makes evaluation of rupture risk important. Our goal was to identify morphological features and anatomical variants associated with PComA aneurysms and to assess parameters related to rupture. We studied CT angiographies of 391 consecutive patients treated between 2000 and 2014 at a single institution. We determined clinically important morphological parameters and performed univariate and multivariate analysis. There were a total of 413 PComA aneurysms: 258 (62%) were ruptured and 155 (38%) unruptured. Ruptured PComA aneurysms had the potential to cause severe bleeding with IVH and/or temporal ICH ($n = 170$, 66% of ruptured). The main types of PComA origin were classified as follows: (1) separate (32%), (2) side by side (21%) and (3) a joint neck with the aneurysm (6%). After the multivariate logistic regression, the morphological parameters related to PComA aneurysm rupture were an irregular aneurysm dome, neck diameter, and aspect ratio >1.5. The most marked morphological features of the PComA aneurysms were: saccular nature (99%), infero-posterior dome orientation (42%), infrequency of large or giant aneurysms (4%), narrow neck compared to the aneurysm size, PComA originating directly from the aneurysm neck or the dome (28%), and fetal or dominant PComA on the side of the aneurysm (35%). There were location-related parameters that were more strongly associated with PComA aneurysm rupture than aneurysm size: an irregular aneurysm dome, larger diameter of the aneurysm neck and aspect ratio >1.5.

Keywords Fetal posterior cerebral artery · Intracranial aneurysm · Morphology · Posterior communicating artery · Posterior communicating artery aneurysm

Introduction

Posterior communicating artery (PComA) aneurysms

Posterior communicating artery (PComA) aneurysms arise from the wall of the internal carotid artery (ICA) at the origin of the posterior communicating artery. They are one of the most common intracranial aneurysms, representing 9–17% of them [5, 9, 17, 29]. Even though PcomA aneurysms are frequently encountered, there are only a few publications on the morphological features of these aneurysms [3, 8, 11, 20, 21, 26, 32].

PComA aneurysms can manifest not only with a rupture causing subarachnoid hemorrhage (SAH), but also in unruptured cases with oculomotor nerve palsy due to compression of the oculomotor nerve by the aneurysm [27]. Nowadays, a growing number of aneurysms are incidental findings, which makes evaluation of rupture risk and of preventive aneurysm treatment important.

The computed tomographic angiography (CTA) has become a primary noninvasive method in the diagnostics of intracranial aneurysms [6, 15, 30]. We are lacking detailed angiographic analysis of PComA aneurysms in large series. There are indications that the PComA diameter, shorter ICA bifurcation-to-aneurysm distance, aneurysm orientation, larger size, neck diameter, aspect ratio, size ratio, inflow angle,

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and a bleb formation or irregular surface may be related to PComA aneurysms or their rupture [3, 8, 11, 20–22, 26]. The previous findings partly contradict each other, which might be due to the relatively small case numbers (*n* = 9–173), differences in inclusion criteria and variable tested parameters in the published series.

The aim of this CTA analysis is to identify morphological features and anatomical variants associated with PComA aneurysms in a large consecutive series to evaluate their clinical significance and to assess the morphological factors related to PComA aneurysm rupture.

Table 1 Clinical presentation (main symptom) of 391 PComA aneurysm patients

Presentation of PComA aneurysm	Patients
Subarachnoid hemorrhage (SAH)	290/74%
Incidental finding	65/17%
Mass effect/OMNP*	23/6%
Screening	10/3%
Other	2/<1%
Epilepsy	1/<1%
Total	391/100%

*OMNP: oculomotor nerve palsy

Patients and methods

Patient and radiological data

This is a retrospective, consecutive, single-institution series of patients treated for a PComA aneurysm between November 2000 and December 2014 at Helsinki University Hospital. This hospital is the sole provider of neurosurgical services throughout Southern Finland (catchment area, 1.8 million people). This study was accepted by Helsinki University Hospital and is based on the Helsinki Cerebral Aneurysm Research Database.

There were a total of 3488 intracranial aneurysm patients admitted to the Helsinki University Hospital between the November 2000 and December 2014. Of these patients, 417 (12%) had PComA aneurysm(s). Clinical manifestations of PComA aneurysm patients are presented in Table 1. The diagnosis of PComA aneurysm was based on computed tomography angiography (CTA), magnetic resonance angiography (MRA) or digital subtraction angiography (DSA). Only patients with pre-treatment CTA were included in this study. Patients with only MRA (*n* = 6) or DSA images (*n* = 10) or with missing preoperative image data (*n* = 5) were excluded. Five patients were excluded because of low preoperative CTA image quality. The final cohort consisted of 391 patients with either ruptured (*n* = 258) or unruptured (*n* = 155) PComA aneurysm(s).

Microneurosurgical (*n* = 315, 76%), endovascular (*n* = 42, 10%) and conservative *n* = 54, 13%) treatment modalities represent the prevailing trend during the era in question. The clinical and radiological data of all the 391 PComA aneurysm patients were reviewed for relevant clinical and radiological information focusing on the morphology and CT angiography analysis.

Radiological parameters

The admission CT and CTA images were evaluated with the Impax Client application using MIP reconstructions. CTAs were obtained with a 32-row helical CT scanner (GE LightSpeed VCT) after administration of a 70-cm^3 intravenous contrast agent (5 ml/s). After the bolus had reached the internal carotid artery at the level of C3–4, the imaging was initiated (slice thickness 0.625 mm, pitch 0.984:1, 120 kV, 100–500 mA; field of view 23 cm, rotation speed 0.4 s). Prior to 2007, we used a multislice helical CT scanner with 4–16 detector rows (GE Lightspeed QX) with fixed timing in contrast administration (18 s prior image acquisitions for patients under 60 years old, 20 s for patients over 60 years old) and 1.25-mm slice thickness. The imaged region started from the level of the first cervical vertebra and continued above the top of the skull.

Measurements included the total number of aneurysms, aneurysm rupture status, PComA aneurysm size (length, width, neck; Fig. 1) and regularity of the dome. The size of the aneurysm was defined as the maximum diameter of the aneurysm. Aspect ratios (length divided by the neck) and bottleneck factors (width divided by the neck) of the ruptured and unruptured aneurysms were calculated. Aneurysm orientation and its relation to the tentorium, mesial temporal lobe and clinoid processes were determined.

Anatomical measurements were also taken of the intracranial internal carotid artery (length, diameter, angle of the supraclinoid ICA using the coronal plane; Fig. 2) and posterior communicating artery (level of the origin from the sagittal plane, diameter, type of origin and existence of anatomical variations using the axial plane). Three-dimensional images were used to evaluate the origin of the PComA if the 2D images were not clearly interpretable.

Typically, the PComA aneurysms project posteriorly or laterally and slightly inferiorly, but some may even have medial projection [18, 32]. To check the different orientations inclusively, we used the classification presented in Table 5. If the aneurysm orientation was in between the two different orientations, the closest was chosen.

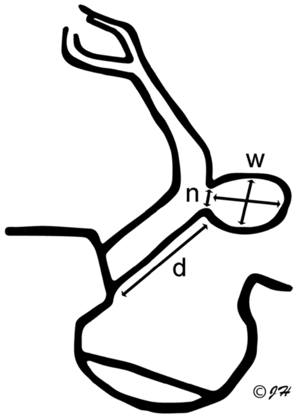

Fig. 1 Anatomical measurement of the PComA aneurysm of the internal carotid artery in sagittal view. n = neck, w = width, l = length, d = distance to the skull base

Statistical analysis

Statistical analysis was made using SPSS and R statistical software. Continuous variables were compared using Student's *t* test and categorical variables using the chi-squared test. Mean values were expressed with standard deviations (SDs).

The parameters found to be statistically significant in univariate analysis were further analyzed using multivariate logistic regression (backward elimination) to identify those that remained significant when accounting for all relevant parameters. *P* values <0.05 were the criteria for statistical significance (using 95% confidence intervals, CIs).

Results

Characteristics of PComA aneurysm patients

The median and mean age of PComA aneurysm patients was 57 years (range 20–92 years, SD ±13), and the majority of patients were females (299 patients, 76%). At least 46% of the patients were current or ex-smokers, 20% were non-smokers, and the rest had unknown smoking status. Most of the patients ($n = 298$, 76%) were treated because of SAH; 291 patients (74%) had classical SAH symptoms, and 23 patients (6%) had oculomotor nerve palsy as a main symptom (Table 1). Some of these patients who sought treatment because of oculomotor nerve palsy had a ruptured PComA aneurysm ($n = 6$); all of them had experienced a severe headache or neck pain in the previous weeks. A smaller proportion of patients was treated solely because of unruptured PComA aneurysm(s) ($n = 95$, 24%, Table 2).

Most patients ($n = 217$, 55%) had a single PComA aneurysm, but as many as 45% of patients ($n = 177$, 45%) had multiple aneurysms. Mirror PComA aneurysm patients were rare ($n = 22$, 5%). Two patients had unruptured AVMs, and both of these patients had six or more aneurysms and exceptional vasculature. One patient had moyamoya disease in addition to the PComA aneurysm.

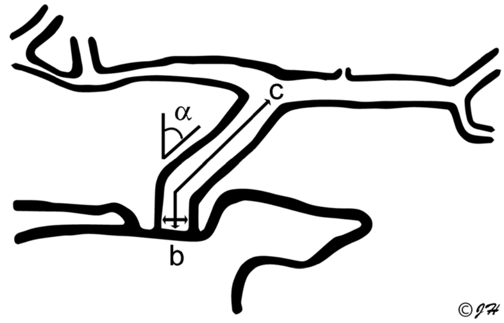

Fig. 2 Measurements taken of the internal carotid artery (ICA), coronal view. α = angle of the supraclinoid ICA; b = diameter of the proximal ICA; c = length of the intracranial ICA

Morphological characteristics of PComA aneurysms and parent vessels

There were a total of 413 PComA aneurysms (391 PComA aneurysm patients, 22 with PComA aneurysms on both sides). Of these aneurysms, 258 (62%) were ruptured and 155 (38%) unruptured. The studied morphological characteristics and results after the univariate analysis of ruptured and unruptured PComA aneurysms are introduced in Table 3.

Size

Most of the ruptured PComA aneurysms were medium sized, 7–14 mm (57%), whereas most unruptured aneurysms were smaller than 7 mm (77%). Among ruptured PComA aneurysms, 38% ($n = 99$) were smaller than 7 mm (Table 4).

Neck, aspect ratio and bottleneck factor

For 90% of the PComA aneurysms, the neck was 5 mm or smaller. Ruptured PComA aneurysms had somewhat wider necks than unruptured PComA aneurysms (Table 3).

Aspect ratios of ruptured PComA aneurysms were larger than aspect ratios of unruptured aneurysms. This was also the case for bottleneck factors of ruptured and unruptured aneurysms (Table 3).

Dome orientation and irregularity

Infero-posterior (Fig. 3), posterior and infero-lateral orientations were the most common alignments among the PComA aneurysms (42%, 20% and 17%, respectively, Table 5). There were only a few aneurysms with medial dome projections ($n = 9$, 2%). Even 90% of the ruptured PComA aneurysms ($n = 231$) had irregular domes as opposed to only 34% of the unruptured ones (Table 3).

Table 2 Rupture status of PComA aneurysms in 391 patients

PComA aneurysm	Female	Male	Total
Ruptured (SAH)	203	53	256/65%
Unruptured PComA aneurysm but another aneurysm ruptured (SAH)	29	13	42/11%
Unruptured	66	27	93/24%
Total	298 (76%)	93 (24%)	391/100%

Morphology of the ICA and the PComA

The diameter of the ICA at the skull base seemed to be slightly smaller among ruptured aneurysms compared to unruptured aneurysms (Table 3). There did not seem to be relevant differences when comparing other characteristics of the parent vessel's ICA and the PComA (length and diameter of the ICA, angle of the supraclinoid ICA, diameter of PComA and level of its origin).

Relations of PComA aneurysms to the surroundings

PComA aneurysm dome, tentorium and mesial temporal lobe

Most of the PComA aneurysms were located supratentorially, above the level where the anterior edge of the tentorium attaches to the anterior clinoid process (70%). About one third were just at the level of the tentorium (28%), and a small proportion of aneurysms was located infratentorially (3%, Table 3). CTA images showed that 49% of the PComA aneurysms ($n = 202$) came in contact with the temporal lobe, some aneurysms even visibly compressing or pushing into the parenchyma. One of these patients had epilepsy as the main symptom of unruptured PComA aneurysm.

Most ruptured PComA aneurysms caused severe SAH (Fischer grade 4 $n = 177$, 69% of all ruptured PComA aneurysms). The typical distribution of severe bleeding was SAH in the basal cisterns with intraventricular hemorrhage ($n = 105$, 41%), temporal intracerebral hemorrhage ($n = 9$, 4%) or both ($n = 56$, 22%, of all ruptured PComA aneurysms). The rest of the PComA aneurysm patients with severe bleeding also had subdural hematomas or frontal intracerebral hematomas ($n = 7$, 3%).

Posterior communicating artery origin and the anterior clinoid process

The origin of the posterior communicating artery varied with respect to the PComA aneurysm neck (Fig. 4a–c). The typical site of origin was medial to the aneurysm and in about third of the cases was clearly separate from the neck of the aneurysm ($n = 134$, 32%), meaning either the artery origin was further

Table 3 Morphological characteristics of 413 PComA aneurysms

Morphological parameters	Ruptured PComA aneurysms $n = 258$	Unruptured PComA aneurysms $n = 155$	Statistically significant difference p Value
Size, mm	7.9 (±3.4)	5.2 (±3.5)	<0.001
Length, mm	7.7 (±3.2)	4.9 (±3.5)	<0.001
Width, mm	5.7 (±3.1)	4.1 (±2.8)	<0.001
Neck, mm	3.7 (±1.6)	3.1 (±1.3)	<0.001
Aspect ratio (length/neck)	2.2 (±0.9)	1.6 (±0.9)	<0.001
Bottleneck factor (width/neck)	1.6 (±0.7)	1.3 (±0.6)	<0.001
Irregular surface (n)	230 (89%)	52 (34%)	<0.001
ICA angle (Fig. 2)	49 (±17.8)	49 (±19.7)	0.984
Lenght of intracranial ICA, mm	10.0 (±2.5)	10.2 (±2.6)	0.393
Diameter of ICA, mm (at the level of the skull base)	3.0 (±0.6)	3.2 (±0.7)	0.004
PComA origin, distance from the skull base, mm	3.3 (±1.9)	3.6 (±2.2)	0.147
Diameter of PComA, mm	1.3 (±0.6)	1.2 (±0.6)	0.091
Fetal PCA (n)	70 (27%)	27 (17%)	0.069
Relation to tentorium			0.014
Supratentorial	173 (67%)	114 (74%)	
At the level of tentorium	81 (31%)	33 (21%)	
Infratentorial	4 (2%)	8 (5%)	
Total	258 (100%)	155 (100%)	

Parameters are presented as mean values (with standard deviation, SD) or number of aneurysms (% within the group)

Table 4 Sizes of ruptured and unruptured PComA aneurysms (% within the group/column)

Size	Ruptured PComA aneurysms n (%)	Unruptured PComA aneurysms n (%)	Total
Small (1–6 mm)	99 (38%)	119 (77%)	218/53%
Medium (7–14 mm)	146 (57%)	31 (20%)	177/43%
Large (15–24 mm)	12 (5%)	5 (3%)	17/4%
Giant (25 mm or larger)	1 (<1%)	0 (0%)	1/<1%
Total	258	155	413/100%

away from the neck of the aneurysm or the vessel leaving next to the neck ran away from the dome. In the other cases, the PComA arose at the aneurysm neck, running close to the dome (n = 88, 21%), or arose directly from the aneurysm dome (n = 26, 6%). In some CTA images, the relation between the origin and the aneurysm was impossible to identify (n = 23, 6%). In most of these cases the PComA was very narrow. The rest of the patients had no visible PComA (n = 142, 34%).

The mean distance between the PComA aneurysm or the PComA origin and the anterior clinoid process, measured from the sagittal images, was 3.4 mm (SD ±2.1 mm). The range was 0–15 mm, and for 15% of aneurysms this distance was only 1 mm or less, reaching close to the skull base.

Posterior communicating artery and vascular anomalies

Fetal PCA and duplication of PCA

Fetal PCA, i.e., an absent or hypoplastic P1 segment with the PCA arising directly from the PComA (Fig. 5), was a common anatomical anomaly; 35% of the PComA aneurysm patients had fetal PCA (24%) or thick, dominant PComA in addition to the PCA (11%) on the same side as the PComA aneurysm. There were no significant differences in posterior communicating artery diameters when comparing ruptured and unruptured PcomA aneurysms (Table 3).

As for another rare anatomical variation, two patients had duplication of the PCA (<1% of patients) as the posterior communicating artery never attached to the PCA but ran alongside to it to the temporo-occipital PCA region (Fig. 6).

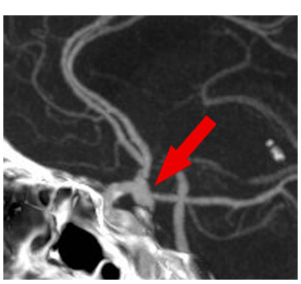

Fig. 3 Infero-posterior dome orientation was the most common PComA aneurysm found in our series. Sagittal CTA image

Multivariate logistic regression on the morphological parameters

The morphological parameters that seemed to be significantly related to PcomA aneurysm rupture after the univariate analysis were larger aneurysm size, length and width, wider diameter of the aneurysm neck, aspect ratio, bottleneck factor, irregularity of the aneurysm dome and aneurysm orientation, the aneurysm's relation to the tentorium and the diameter of the ICA.

After the multivariate logistic regression, the statistical significance was retained for the irregular aneurysm dome, diameter of the aneurysm neck, diameter of the ICA at the skull base and aspect ratio >1.5 (Table 6).

Discussion

PComA aneurysm rupture risk and morphology

PComA aneurysms may differ from other locations of the anterior circulation aneurysms regarding the rupture risk [10, 23, 29], and our results suggest that there are location-related morphological factors that might be helpful in the evaluation of PComA aneurysms. These parameters related to PComA aneurysm rupture were an irregular aneurysm dome, larger diameter of the aneurysm neck, aspect ratio >1.5 and a narrow ICA diameter at the skull base.

The differences among the diameter of the ICA at the skull base were minor, and when regarding the limitations in measurement accuracy, the difference might not have meaning in clinical practice, at least the relevance of this parameter should be interpreted with caution.

Statistical and clinical significance of the main morphological factors

Morphology

PComA aneurysms are typically saccular (99%) and small (53%). They represent the so-called classic, berry-like intracranial aneurysms. In our series, 90% of the ruptured PComA aneurysms (n = 231) had an irregular dome as opposed to only 34% for the unruptured ones (n = 53). This is in line with a

Table 5 PComA aneurysm dome orientations

Orientation of PComA aneurysm	Ruptured PComA aneurysms n	Unruptured PComA aneurysms n	Total
Infero-posterior	95	80	175/42%
Posterior	58	22	80/19%
Supero-posterior	8	3	11/3%
Infero-lateral	40	30	70/17%
Lateral	42	15	58/14%
Supero-lateral	10	1	11/3%
Infero-medial	2	3	5/1%
Medial	2	0	2/<1%
Supero-medial	1	1	2/<1%
Total	258	155	413/100%

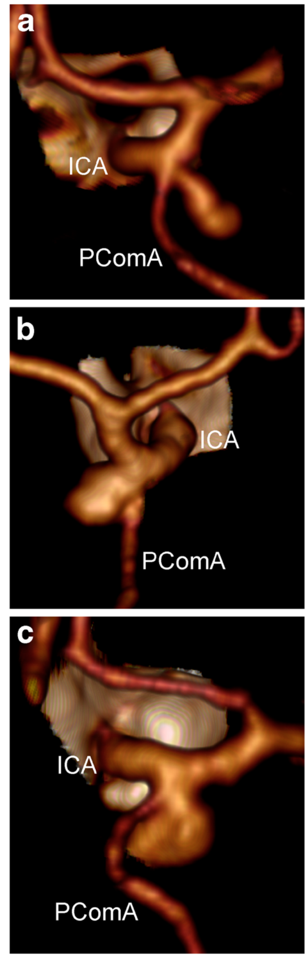

Fig. 4 Different types of PComA origin: **a** Separate; the origin is separate from the neck of the PComA aneurysm. **b** Side by side; the origin arises at the neck of the PComA aneurysm running close to the dome. **c** Joint neck; the origin arises directly at the PComA aneurysm dome

recent publication on morphology of all aneurysm locations (92% irregular shape for ruptured, 22% for unruptured aneurysms) [18]. Aneurysm dome irregularity or lobulations have been associated with rupture risk [18, 22, 23]. There are some restrictions, however, when evaluating regularity of the dome. Ruptured aneurysms are usually found as a result of bleeding. It is not known whether the irregular shape of the dome is a predictor of bleeding or if it is only a result of bleeding. There are indications, though, that prior to rupture, aneurysm wall irregularity increases with the histological wall degeneration, which is related to an increased risk of rupture [7, 16]. These factors together suggest that an unruptured PComA aneurysm with an irregular surface might be at higher risk of rupture than an unruptured PComA aneurysm with a smooth surface.

Dome orientation

Infero-posterior dome orientation was the most common projection among PComA aneurysms (42%, Fig. 3). Many PComA aneurysms had some lateral orientation as well, which, together with their supratentorial nature (70%), explains why half of all PComA aneurysms came in contact with the temporal lobe (n = 202, 49%) and had a potential to cause a severe bleeding with IVH and/or temporal ICH (n = 170, 66% of ruptured PComA aneurysms).

Two earlier studies suggest that lateral or supero-lateral orientations of PComA aneurysms might be high-risk orientations regarding the rupture [22, 26]. Also one recent publication reported that a larger inflow angle, which can be associated with more superior PComA aneurysm dome orientation, was considered to be related to aneurysm rupture risk [21]. Even though we studied different orientations inclusively, our results did not support these earlier findings as there were no statistically significant differences in orientations (horizontal or vertical) of ruptured and unruptured aneurysms after the multivariate analysis.

The aneurysm dome orientation is considered an important factor for microsurgical clipping of these lesions. Posterior orientations of the PComA aneurysm dome, 64% in our series, may be more challenging surgically than the more lateral ones. A recent study by Fukuda et al. suggested that PComA aneurysms with posterior orientation have a higher incidence of intraoperative rupture and procedure-related infarctions and required complex clipping more often than those with a lateral orientation [8]. With posterior dome orientation, visualization of the neck and the dome of the aneurysm may be obstructed by the internal carotid artery. Also the perforators arising from both the ICA and PComA are more difficult to identify and secure. The aneurysm dome orientation has less clinical significance in endovascular treatment.

Aneurysm size

Aneurysm size has been strongly related to the risk of rupture [12–14, 23, 24, 28, 29]. Ruptured aneurysms tend to be larger

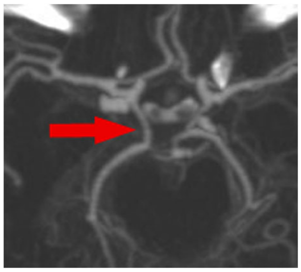

Fig. 5 Fetal PCA, a common anatomical anomaly, on the right side. Axial CTA image

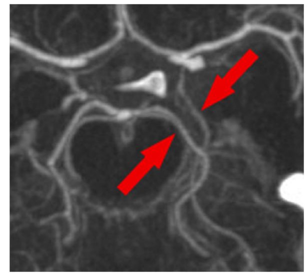

Fig. 6 Duplication of the PCA, a rare anatomical anomaly on the left side. Axial CTA image

than unruptured ones. This was true for our series as well. However, aneurysm size should not be the sole factor on which the treatment decisions are based, since 38% of the ruptured PComA aneurysms were smaller than 7 mm. In addition to aneurysm morphology, the age and sex of the patient, as well as smoking habits and other comorbidities, should be taken into account.

Large or giant PComA aneurysms were infrequent (Table 4). Also Yasargil's PComA series showed only a few large PComA aneurysms (2% of all 173). It was speculated that PComA aneurysms seldom get to grow large because of early symptoms caused by the close proximity of the oculomotor nerve [32]. Another explanation could be that PComA aneurysms have a greater rupture risk when compared to other locations of anterior circulation aneurysms, so they do not reach a large size before rupturing [10, 23, 29]. Our results suggested that, for PComA aneurysms, other location-related morphological parameters were more strongly associated with the PComA rupture status than size.

Aneurysm neck and PComA origin

The neck of a PComA aneurysm is typically narrow in comparison to its dome, and a larger aneurysm neck diameter seems to be related to a higher incidence of rupture. This finding is similar to those reported by a publication on PComA aneurysm morphology a few years ago [11]. A large portion of unruptured PcomA aneurysms was small and regular shaped, whereas most ruptured ones had a larger aspect ratio and bottleneck factor, meaning they often were more oblong or rotund shaped with a narrower neck compared to the dome. In addition to describing the shape of the aneurysm, the aspect ratio also seems to be related to the aneurysm rupture. However, there are limitations to using this parameter in everyday practice, as we do not know where the clinically significant threshold values lie. In the present series, an aspect ratio >1.5 was associated with rupture, which seems to be in line with previous articles evaluating the aspect ratio (or dome to neck ratio) and rupture risk [10, 22].

The origin of the PComA with respect to the aneurysm neck is a clinically important factor for both endovascular and microsurgical treatment [1, 4, 19, 25, 32, 33]. In about a third of the cases, a PComA origin was separate from the neck of the aneurysm or the vessel coursed away from the aneurysm dome (Fig. 4 a). This would be the optimal configuration from the treatment point of view. However, in 28% of patients the PComA arose just at the aneurysm neck running close to the dome or from the dome directly (Fig. 4 b and c). In these configurations, the risk of accidental occlusion of the PComA might be higher irrespective of the treatment method. Especially in cases with the PComA arising directly from the aneurysm dome, coiling or clipping is usually not possible without either compromising the posterior communicating artery or leaving a neck remnant.

Vascular anomalies

Fetal PCA (PComA with an absent or hypoplastic P1 segment) was the most common anatomical anomaly in patients with PComA aneurysms (24%, Fig. 5). A similar prevalence of fetal PCA (25%) was previously reported by Yasargil based on a cadaver study [30]. Another rarely seen anomaly is the duplication of the PCA (n = 2, <1% Fig. 6). This configuration was previously described by Yasargil and by a few case reports [2, 31].

One important goal in the treatment of PComA aneurysms, in addition to taking care of the aneurysm itself, is preserving the posterior communicating artery [1, 4, 25, 32, 33]. In two small recent series, obstructing the flow in a hypoplastic PComA was not related to major complications [1, 4]. Diminished flow in PComA may, however, be a source of delayed thromboembolic infarction

Table 6 Results of the multivariate logistic regression analysis on morphological parameters related to rupture status of PComA aneurysms

Parameter	Odds ratio	95% CI	p value
Irregular surface	0.12	0.07–0.22	<0.001
Neck (diameter) of the aneurysm	1.30	1.07–1.61	0.012
Aspect ratio >1.5	2.26	1.26–4.04	<0.001
Diameter of the ICA	0.50	0.32–0.75	0.006

[4]. Preserving the artery is particularly important in patients with a fetal PCA or a thick PComA because its obliteration poses a substantial risk for infarction and neurological sequelae [33]. Duplication of the PCA probably should be preserved equally carefully as the fetal type PCA. The diameter of the PComA was not statistically related to rupture, but it has evident significance in clinical work.

Limitations

Restrictions of CTA analysis

In CTA images, the anterior choroidal artery (AChA) could only be seen faintly if at all, and there were times when even the PComA artery could not be seen. Also antero-thalamic perforators or other small vessels could not be seen on the CTA images. DSA images have better resolution when it comes to smaller vessels but restrictions concerning less vascularized structures and bony landmarks. In selected cases, for example in aneurysms with challenging morphology, the DSA still gives valuable information in addition to the CT angiography.

There was variation in the CTA image quality at the beginning of the twenty-first century, and since then the imaging technique has improved. More recently, approximately in the last 10 years, the quality has become more standard. Some images from earlier years were missing parts of the original data, making it more difficult to obtain good 3D image reconstructions.

Limitations of the study design

Despite of the high inclusion rate of treated PComA aneurysm patients, some aSAH patients died before reaching the hospital, causing bias in patient selection. Also, it is not known whether the aneurysm characteristics change as a result of bleeding. Because prospective aneurysm studies often have a high selection bias and true natural history series are impossible to carry out nowadays (high-risk lesions will be treated), retrospective series have their place as minimally selective, consecutive series, representing the variety of treated patients.

In the evaluation of PComA aneurysm morphology, our aim was to choose clinically important morphological characteristics. However, the list is not all inclusive. For example, hemodynamic calculations were not included even though hemodynamic factors probably do play a role in aneurysm formation and growth and also could offer a useful additional tool for the evaluation of aneurysm rupture risk in the future. The use of hemodynamic parameters is still restricted by their complicated mathematical models, which have not yet been introduced into clinical practice.

Conclusions

In this large consecutive series, the most marked morphological features of the PComA aneurysms were: (1) the saccular nature (99%), (2) infero-posterior dome orientation (42%), (3) infrequency of large or giant aneurysms (4%), (4) narrow neck compared to the aneurysm size, (5) PComA originating directly from the aneurysm neck or dome (28%), and (6) a fetal or dominant PComA on the side of the aneurysm (35%). There were location-related morphological parameters that were associated with PComA aneurysm rupture even more strongly than aneurysm size: an irregular aneurysm dome, larger diameter of the aneurysm neck and aspect ratio >1.5.

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Compliance with ethical standards

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Conflict of interest None.

Ethical aspects The authors have followed good ethical research practice. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This is a retrospective, register-based study. For this type of study formal consent is not required.

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Comments

The authors present a thorough evaluation of the morphological characteristics of a large series of consecutive posterior communicating artery aneurysms treated at their institution over a 4-year period. Measurements of the morphology of the aneurysms were performed on preoperative CTA studies. The ruptured vs. unruptured status of the aneurysm at the time of treatment was used to correlate the morphology with risk of rupture.

The study design has inherent flaws. There is selection bias as the authors only evaluated treated aneurysms. Unruptured aneurysms that were followed in their institution were not included in the analysis, which might have introduced bias. In addition, the status of the aneurysm at the time of treatment is an arbitrary parameter to rate risk of rupture. Indeed, many aneurysms in the "low-risk" unruptured state may have represented higher risk lesions that happened to be discovered and treated before rupture. In addition, morphology is only a single parameter in a large range of other factors related to hemorrhage. The authors point out that hemodynamics is another factor that was not evaluated. Increasing data in the literature also identify inflammatory mechanisms involved in aneurysm rupture.

Despite the study design issues, it is a welcome addition to the cerebrovascular literature. Accounting for all factors related to aneurysm rupture would be very difficult, and defining morphological factors that may represent higher risk in a large series of aneurysms is important. In addition, as the authors state, true natural history studies of aneurysm rupture risk are almost impossible today.

Neurosurgeons who treat cerebral aneurysms are always confronted with the dilemma of how to decide which unruptured aneurysms need to be treated. The stakes are high as subarachnoid hemorrhage is associated with significant morbidity and mortality; however, treatment of aneurysms also poses a risk to the patient. The size of the aneurysm alone is not an effective determining parameter. Indeed, in this study 38% of ruptured PCOM aneurysms were small in size. Additional morphological factors associated with hemorrhage as identified in this study will be beneficial to aid neurosurgeons with this difficult question.

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