Radiometric analysis of paraclinoid carotid artery aneurysms

Yuichiro Tanaka, M.D., Kazuhiro Hongo, M.D., Tsuyoshi Tada, M.D., Hisashi Nagashima, M.D., Tetsuyoshi Horiuchi, M.D., Tetsuya Goto, M.D., Jun-ichi Koyama, M.D., and Shigeaki Kobayashi, M.D.

Department of Neurosurgery, Shinshu University School of Medicine, Matsumoto, Japan

Object. Classification of paraclinoid carotid artery (CA) aneurysms based on their associated branching arteries has been confusing because superior hypophyseal arteries (SHAs) are too fine to appear opacified on cerebral angiograms. The authors performed a retrospective radiometric analysis of surgically treated paraclinoid aneurysms to elucidate their angiographic and anatomical characteristics.

Methods. A retrospective analysis was made of 85 intradural paraclinoid aneurysms in which the presence or absence of branching arteries had been determined at the time of surgical clipping. The lesions were classified as supraclinoid, clinoid, and infraclinoid aneurysms based on their relation to the anterior clinoid process on lateral angiograms of the CA. The direction of the aneurysms were measured according to angles formed between the medial portion of the horizontal line crossing the aneurysm sac and the center of the aneurysm neck on anteroposterior angiograms.

Branching arteries were associated with 68 aneurysms, of which 28 were ophthalmic artery (OphA) lesions (32.9%) and 40 were SHA ones (47.1%); associated branching arteries were absent in 17 aneurysms (20%). Twenty-five aneurysms (29.4%) were located at the supraclinoidal level, 46 (54.1%) at the clinoidal, and 14 (16.5%) at the infraclinoidal. The majority of aneurysms identified at the supraclinoidal level were OphA lesions (44%) or those unassociated with branching arteries (48%), with mean directions of 57° or 67°, respectively. At the clinoidal level, the mean directions of aneurysms were 76° in six lesions unassociated with branching arteries (13%), 43° in 16 OphA lesions (35%), and −11° in 24 SHA ones (52%). All aneurysms at the infraclinoidal level arose at the origin of the SHAs, with a mean direction of −29°, and most of these were embedded in the carotid cave.

Conclusions. Aneurysms arising from the SHA can be distinguished from those not located at an arterial division by cerebral angiography, because SHA lesions are usually located at the medial or inferomedial wall of the internal carotid artery at the clinoidal or infraclinoidal level. Their distribution correlates well with the reported distribution of SHA origins. The carotid cave aneurysm is a kind of SHA lesion that originates at the most proximal intradural CA.

Key Words • internal carotid artery • cerebral aneurysm • paraclinoid carotid artery aneurysm

Intradural CA aneurysms originating from the ICA between the distal dural ring and the PCoA are often referred to as paraclinoid aneurysms in recent literature. Authors have assigned various designations to these aneurysms or subgroups, such as “CA–OphA,” “ventral ICA,” “CA paracoid,” “infra-OphA,” “ventral paracoid,” “carotid cave,” “SHA,” “transitional,” “posterior CA wall,” and “juxta-dural ring” aneurysm. The variety in terminology is attributable to the complex paraclinoid anatomy and to the limitations of cerebral angiography, which is incapable of revealing SHAs. Day proposed the first comprehensive and systematic classification of paraclinoid aneurysms based on the branching arteries located there, and those that did not arise at the OphA were collectively referred to as SHA lesions. He and other researchers, however, did not describe whether the so-called SHA aneurysms always have a clear relationship with the SHA;3 some CA aneurysms are known to arise in areas in which there is no arterial division.14,17,18,21–23 We therefore performed a retrospective radiometric analysis of surgically treated paraclinoid aneurysms to elucidate their angiographic and anatomical characteristics.

Clinical Material and Methods

One hundred fifty-seven intradural paraclinoid aneurysms were treated between 1991 and 2000 at the Shinshu University Hospital and its affiliated hospitals. Neck clipping was performed in 122 aneurysms, wrapping in two, trapping–bypass in three, and coil embolization in 30. Among 124 aneurysms in which the necks were directly observed, 39 were excluded from the study for the following reasons: 1) observation of the entire aneurysm neck was obscured by the lesion itself or by the ICA; 2) dense sub-
arachnoid clots restricted observation; or 3) both the OphA and an SHA were involved in the aneurysm neck and a single contributing branch was not defined. In some carotid cave aneurysms, an SHA was considered to be a branching artery insofar as the lesion was located in the carotid cave, and an SHA emerged from the carotid cave even when the origin of the particular SHA could not be observed directly. Finally, 85 paraclinoid aneurysms were selected for the present study. The patient population consisted of 23 men and 62 women, ranging in age from 21 to 76 years (mean 55.6 ± 12.5 years). Thirty-eight aneurysms were located on the right ICA and 47 on the left ICA. There were four ruptured paraclinoid aneurysms and the other 81 were unruptured. Associated aneurysms were found in 34 patients (40%) and 11 of these had ruptured. A nonfunctioning pituitary adenoma was associated in three patients and a ruptured dissecting vertebral artery aneurysm in one. Observation of the aneurysm neck was gained via the ipsilateral transsylvian route in 62 aneurysms and via the contralateral route in 23 lesions.

Paraclinoid aneurysms were categorized as occurring at the supraclinoidal, clinoidal, and infraclinoidal levels based on the anatomical relationships of the aneurysm necks to the anterior clinoid process as they appeared on lateral angiograms of the CA (Figs. 1 and 2). The direction in which the aneurysm neck lay was measured as the angle formed between the medial portion of the horizontal line that crosses the aneurysm sac and the center of the aneurysm neck as they appear on anteroposterior (A-P) angiograms.

Fig. 1. Illustrations and associated angiogram showing the method used to measure the level and direction of paraclinoid aneurysms. Left: Paraclinoid aneurysms were categorized as supraclinoid, clinoid, and infraclinoid based on their relations to the anterior clinoid process as they appear on lateral angiograms of the CA. Center and Right: The direction of each aneurysm was measured as the angle formed between the medial portion of the horizontal line that crosses the aneurysm sac and the center of the aneurysm neck as they appear on anteroposterior (A-P) angiograms.

Fig. 2. Lateral (upper row) and anteroposterior (lower row) angiograms demonstrating aneurysms at the supraclinoidal (A and B), clinoidal (C and D), and infraclinoidal (E and F) levels. The direction of the supraclinoid aneurysm (B) was 7° and, at the time of clipping, it was proved to arise from a site at which there was no branching artery. The direction of the clinoid aneurysm (D) was 14° and it originated at the origin of an SHA. The direction of the infraclinoid aneurysm (F) was −35° and it was located at the junction of the ICA and an SHA.
Radiometric analysis of paraclinoid carotid artery aneurysms

of contrast material, to determine the relationship between the aneurysm neck and the anterior clinoid process. In cases in which conventional serial angiograms were unavailable and bone structures had been eliminated on images obtained using digital subtraction angiography, the arterial phase of the digital subtraction images was magnified and superimposed correctly over plain skull x-ray films to determine the level of the aneurysm neck. Data were reported as the means ± standard deviation. Paired comparisons were made using the Student t-test.

Results

Arteries identified as having a clear association with the aneurysm neck included OphAs among 28 lesions (32.9%) and SHAs among 40 (47.1%); associated branching arteries were absent among 17 aneurysms (20%). Mean diameters of aneurysms were $8.3 \pm 64$ mm (range 3–25 mm) in the OphA lesions, $3.9 \pm 1.5$ mm (range 2–8 mm) in SHA ones, and $5.2 \pm 1.7$ mm (range 3–9 mm) in those unassociated with branching arteries. Twenty-five aneurysms (29.4%) were located at the supraclinoidal level, 46 (54.1%) at the clinoidal, and 14 (16.5%) at the infraclinoidal (Fig. 3). At the supraclinoidal level, the mean size of the aneurysms was $7.3 \pm 6.2$ mm (range 3–25 mm); at the clinoidal level, the mean size was $5.2 \pm 3.3$ mm (range 2–20 mm); and at the infraclinoidal level, it was $4 \pm 1.8$ mm (range 3–8 mm). Aneurysms originating at the junction of the ICA and OphAs and those located at sites at which there was no branching artery were found exclusively at supraclinoidal and clinoidal levels. The mean directions of OphA aneurysms and ones unassociated with arterial branches, respectively, were 57° and 67° at the supraclinoidal level, and 29° at the clinoidal level (Fig. 4). On the other hand, SHA aneurysms occurred at all three levels and displayed mean directions of $-21^\circ$ at the supraclinoidal level, $-11^\circ$ at the clinoidal level, and $-29^\circ$ at the infraclinoidal level. Most infraclinoidal aneurysms (92.9%) were embedded in the carotid cave and one clinoid aneurysm was found in the carotid cave (Fig. 5). The entire aneurysm body was fragile in five of the 17 aneurysms unassociated with branching arteries. The mean direction of these fragile aneurysms was $90.2^\circ$, whereas that of the nonfragile aneurysms not associated with branching arteries was $61.9^\circ$ (no significant difference).

Discussion

We performed a retrospective radiometric analysis of 68 paraclinoid aneurysms to elucidate their angiographic and anatomical characteristics. In 33% of these aneurysms, the OphA was the associated branching artery, in 47% the SHA was the associated branching artery, and in 20% no branching artery was observed. Aneurysms located at sites at which there was no branching artery usually projected superiorly at the supraclinoidal and clinoidal levels. The SHA aneurysms can be distinguished from those lesions by using cerebral angiography; that is, aneurysms arising from the SHA usually project medially or inferomedially at the clinoidal or infraclinoidal level. All aneurysms at the infraclinoidal level arose at the origin of an SHA. Carotid cave aneurysms constitute a subgroup of SHA lesions that originate at the most proximal intradural CA.

An OphA is a single branching artery that can be seen on cerebral angiograms to lie in the paraclinoid CA segment between the distal dural ring, including the carotid cave, and the origin of the PCoA. Also present in the paraclinoidal area is at least one SHA, but these arteries are usually too fine to be revealed by angiography because, in general, they are smaller than 0.5 mm in outer diameter (mean outer diameter 0.2 mm). They mainly originate at the medial wall of the intradural ICA and range in number from one to five (in the literature, mean numbers of SHAs range from 1.8 to 2.2). We found that the majority of SHA aneurysms are located at clinoidal and infraclinoidal levels, although they arise at any level of the paraclinoid segment of the CA. This distribution pattern of SHA aneurysms agrees with that posited in the literature in which such lesions have been shown to arise predominantly (85%) at the first 5 mm of the intradural ICA. In the literature so-called SHA lesions have been defined as paraclinoid aneurysms whose necks are located at the medial or inferomedial wall of the ICA, without an association with an OphA. Day reported that 51.3% of paraclinoid aneurysms were OphA lesions, and the other 48.7% were SHA ones. His proposal that non-OphA aneurysms could be lesions of the SHA is partly supported by our observation that the majority (70.2%) of aneurysms that have no association with an OphA proved to arise from the junction of the ICA and an SHA. Regardless, the existence of lesions unassociated with branching arteries cannot be ignored because in the present series they constituted 20% of all paraclinoid aneurysms.

Aneurysms of the ICA that have no relation to any arterial divisions have been variously described as selerotic aneurysms, distal medial wall or superior wall ICA aneurysms, dorsal ICA aneurysms, and blood blister–like aneurysms. Some of them are very fragile and special attention must be paid during surgery when they are exposed by retracting the frontal lobe, because these aneurysms adhere to the frontal base and the neck is often lacerated. The ICA aneurysms located at sites at which there is no branching artery are usually identified at the segment between the origin of the PCoA and the distal ICA bifurcation; however, such aneurysms are also found to arise from the segment proximal to the origin of the PCoA, as further supported by data from the present study. Ogawa, et al., reported finding 48 aneurysms located at nonbranching sites of the ICA and arising from its
superomedial aspect, including 40 blister-type fragile aneurysms and eight saccular type aneurysms that had relatively firm necks similar to ordinary berry aneurysms. On the other hand, ordinary aneurysms were seen more often than fragile ones in the present series. Possible explanations for this difference include the fact that unruptured aneurysms were dominant in our series and that the lesions examined were restricted to the paraclinoid segment. An accurate preoperative diagnosis of dorsal ICA aneurysms is important to avoid catastrophic bleeding at surgery, and lesions unassociated with branching arteries should be distinguished from OphA ones because their neck levels and directions are similar, as shown in Fig. 4. Extreme care should be taken with superiorly projecting supraclinoid and clinoid aneurysms that originate at sites at which no arterial branching is confirmed angiographically, because true SHA lesions do not project superiorly (Fig. 4).

Carotid cave aneurysms are defined as the most proximal intradural ICA lesions embedded in the carotid cave at the level of the distal dural ring. They are located below the plane of the dural ring, but are basically intradural. Most carotid cave aneurysms were demonstrated as inferomedially projecting lesions at the infraclinoidal level in the present study, although there was one whose neck was located

---

**Fig. 4.** Diagrams in which the lines in each circle depict the direction of aneurysms at sites at which there is no branching artery (left), as well as OphA (center) and SHA (right) lesions at different levels. The mean direction of aneurysms in each subgroup is indicated. Black dots indicate fragile aneurysms. n = number of aneurysms.

**Fig. 5.** Diagram in which the lines in each circle show the direction of aneurysms at the various levels. Black and gray lines indicate aneurysms located inside and outside the carotid cave, respectively. I = inferior; L = lateral; M = medial; S = superior.
Radiometric analysis of paraclinoid carotid artery aneurysms

at the clinoidal level. Carotid cave aneurysms can be considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.1,10 The carotid cave has been identified in 68 to 77% of nondiseased cadaveric specimens.7,10 Aplasia or hypoplasia of the carotid cave is a noted finding in up to 93% of the diseased cases.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10 The carotid cave has been considered to be SHA lesions that arise from the most proximal portion of the intradural ICA.3,10

References


Manuscript received June 6, 2001. Accepted in final form November 20, 2001.

Address reprint requests to: Kazuhiro Hongo, M.D., Department of Neurosurgery, Shinshu University School of Medicine, 3-1-1 Asahi, Matsumoto 390–8621, Japan.