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Anatomy

The Surgical Anatomy of the Perforating Branches of the Anterior Choroidal Artery

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BACKGROUND
The available information about certain microanatomic features of the AChA perforators is incomplete. Precise knowledge of these vessels is necessary to understand the consequences of their occlusion and to safely operate in their region.

METHODS
The AChA perforators were microdissected and examined under the stereoscopic microscope in 10 vascular casts and in 20 hemispheres injected with india ink or radiopaque substance.

RESULTS
The perforating branches ranged in number from 2 to 9 (mean, 4.6) and in diameter between 90 μm and 600 μm (mean, 317 μm). The most proximal perforator arose 3.2 mm on average caudal to the AChA origin. The most distal (capsulothalamic) perforator varied in size from 200 μm to 610 μm (mean, 431 μm). One or more of the perforators always originated from the AChA (100%), but some of them also from the uncal (33.3%) or parahippocampal branch (10%) of the AChA, either as individual vessels only (70%) or from common trunks (30%). The perforators gave off the peduncular (20%), optic (23.3%), or uncal side branches (26.7%).

CONCLUSIONS
Our findings concerning the origin, position, number, size, branching, penetration site, and relationships of the AChA perforators gave the anatomic basis for safe operations in patients with AChA aneurysms or mediobasal limbic epilepsy.

KEY WORDS
Perforating artery, anterior choroidal artery, cerebral artery.

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Many authors have examined the anterior choroidal artery (AChA) [1,4,6,8,10,15,16,22,23, 25–27,29,31,32]. Although a few of them have paid attention to the perforating branches of the AChA [1,6–8,15,17,26,27,29], none of the investigators, to our knowledge, has devoted articles specifically to the AChA perforators. Since the latter vessels are of great clinical significance [2,3,5,9,11,12,14,24,33], we have decided to examine the AChA perforators in detail.

Material and Methods

Thirty-four cerebral hemispheres of individuals aged between 27 and 76 years were obtained from routine autopsies as soon as possible after death. The arterial system of the hemispheres was perfused with isotonic saline solution and then with a 10% mixture of gelatin and india ink (18 hemispheres) or a radiopaque substance (4 hemispheres), or with methyl methacrylate (12 hemispheres). The specimens injected with india ink and Micropaque® were fixed in 10% formaldehyde solution for 3 weeks, while those injected with methylmethacrylate were immersed in potassium hydroxide for 6 days to obtain the vascular casts. The 30 best prepared hemispheres were selected for this study, i.e., 10 vascular casts and 20 injected specimens.

After microdissecting the cerebral arteries, the AChA perforators were examined under the stereoscopic microscope. Drawings were made and photographs were taken of each AChA and its perforators. A separate illustration was made (Figure 1) to show the magnified parts in Figures 2 and 4. The diameter of the vessels was measured using the

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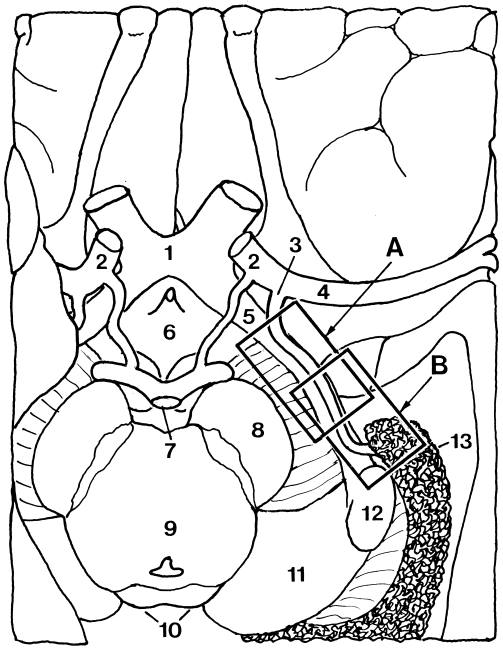


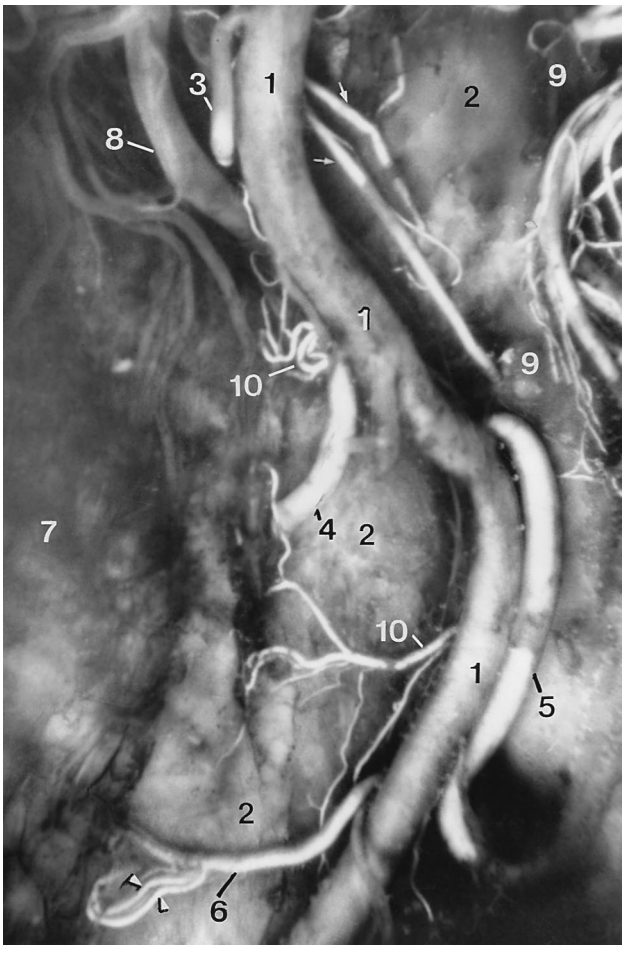
1 Basal view of brain after transverse section of midbrain and partial excision of left temporal lobe to show magnified portions in Figure 2 (rectangle A) and in Figure 4 (rectangle B). The optic chiasm (1). The internal carotid artery (2). The left anterior choroidal artery (3). The middle cerebral artery (4). The optic tract (5). The hypothalamus (6). The basilar artery (7). The cerebral peduncle (8). The tegmentum (9) and the inferior colliculi (10) of the midbrain. The pulvinar (11). The lateral geniculate body (12). The choroid plexus (13) of the inferior horn of the ventricle.

ocular micrometer. The mean values were calculated from all the measurements obtained.

Results

The perforating branches were noted to arise along the entire cisternal segment of the AChA (46.7%) (Figure 2) or from its proximal and distal thirds (53.3%). The most proximal perforator may arise from the origin site of the AChA (6.7%) or at a distance between 0.1 mm and 12.4 mm from the AChA origin. The majority of them, however, arose very close to the AChA origin (mean, 3.2 mm) (Figure 3). The other proximal perforators were in close proximity to the perforators of the ICA and to the premammillary branch of the posterior communicating artery (Figures 2 and 3).

The most distal perforator, usually single, most often originated close to the lateral geniculate body, just in front of the inferior horn of the ventricle (Figure 4). This perforator, known as the capsulothalamic artery, commonly was larger than the

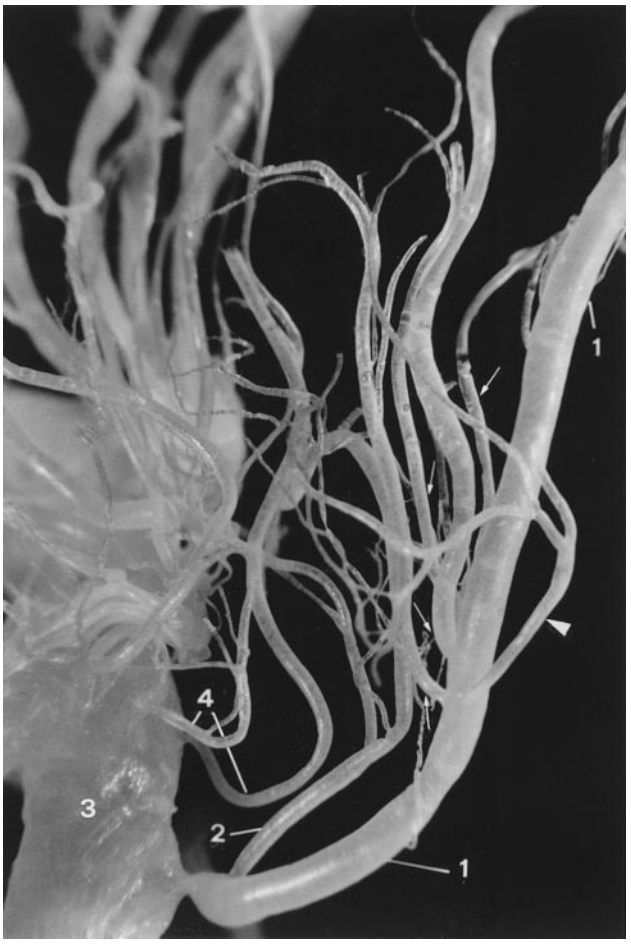


2 Basal view of left AChA (1) which follows the optic tract (2). The AChA gives off four perforating branches (3 through 6). The first perforator (3) divides into two branches (*arrows*). The second one (4) enters the brain just medial to the optic tract. The third perforator (5) represents the capsulothalamic artery. The fourth perforator (6) gives off two twigs (*arrowheads*) to the cerebral peduncle (7). The premammillary artery (8). The caudomedial part of the anterior perforated substance (9). The optic branches of the AChA (10). (The magnified part corresponds to rectangle A in Figure 1).

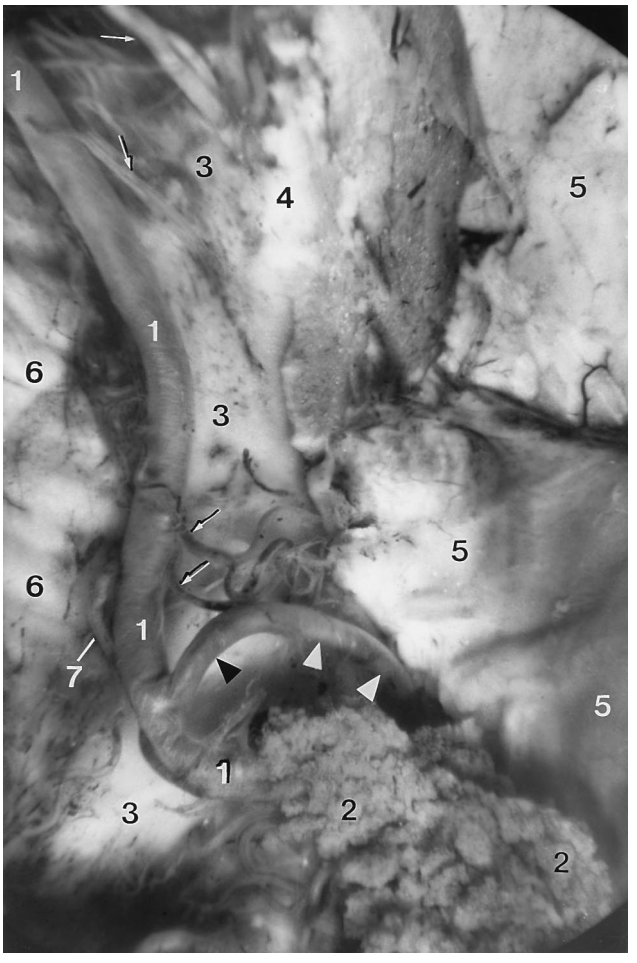
other perforating vessels and it varied in size from 200 μm to 610 μm (mean, 431 μm). The capsulothalamic artery rarely arose from the middle third of the AChA (Figure 2). The artery continued caudally, just dorsal to the inferior horn.

The remaining distal and proximal perforators ranged in diameter between 90 μm and 600 μm (Table 1). The AChA perforators varied from 2 to 9 in number (Table 1). In cases with a smaller number of AChA perforators (10%), the ipsilateral ICA gave rise to several more perforators than usual, which arose from a common trunk.

The perforating branches may originate from the AChA as individual vessels (70%), but also from



3 Medial and slightly oblique view of the right AChA (1) of vascular cast. Note perforating branch (2) arising close to the AChA origin; remaining perforators (*arrows*); and uncal branch (*arrowhead*). Internal carotid artery (3) and its perforators (4).



4 Basal view of a large capsulothalamic perforator (*arrowheads*) that arises from the left AChA (1) just rostral to the inferior horn and choroid plexus (2) of the lateral ventricle. The other perforators are indicated by *arrows*. The optic tract (3). The anterior perforated substance (4). The cut surface of the temporal lobe (5). The cerebral peduncle (6). The peduncular branch of the AChA (7). (The magnified part corresponds to rectangle B in Figure 1).

their own common trunks (30%). The common trunks usually were larger than the individual perforators (Table 1). The trunks, which were occasionally very short, most often divided into two individual perforators (Figure 5). The diameters of latter perforators measured between 130 μm and 480 μm (mean, 322 μm).

In addition to the origination from the AChA trunk, some perforators were occasionally seen to arise in common with or from the side branches of the AChA (Table 1), especially from the uncal twigs (Figure 6) or the parahippocampal branches. The uncal vessels, which gave off the perforators, ranged in size from 320 μm to 500 μm (mean, 441 μm), whereas the corresponding parahippocampal vessels varied between 500 μm and 600 μm (mean, 537 μm). The perforators originating from these leptomeningeal vessels measured in diameter from 90 μm to 400 μm (mean, 222 μm). The perforating vessels very rarely arose in common with the temporopolar or a choroidal branch of the AChA.

After leaving the AChA or its leptomeningeal branches, the perforating vessels coursed more or less obliquely, usually across the optic tract, in a caudal, dorsal, and lateral or medial direction (Figures 2–6). The perforators entered the caudal part of the anterior perforated substance (Figures 2 and 4), close to the ICA perforators and/or the uncal and parahippocampal branches of the AChA; the region medial to the optic tract (Figure 2), where they usually entered the cerebral peduncle; and the optic tract itself (Table 1). The latter perforators (Figure 7) ranged in diameter from 120 μm to 360 μm (mean, 236 μm). Regardless of their penetration

1 Characteristics of the Perforators of the Anterior Choroidal Artery

ORIGIN (%)*	NUMBER/RANGE (MEAN)	DIAMETER (μM) OF INDIVIDUAL PERFORATORS: RANGE (MEAN)	DIAMETER (μM) OF COMMON TRUNKS: RANGE (MEAN)	PENETRATION SITE*			SIDE BRANCHES*		
				MEDIAL TO THE TRACT	THE TRACT ITSELF	LATERAL TO THE TRACT	UNCAL	OPTIC	PEDUNCULAR
AChA (100.0)	2–9 (4.6)	90–600 (317)	330–620 (467)	43.3%	13.3%	100.0%	26.7%	23.3%	20%
Uncal branch (33.3)									
Parahippocampal branch (10.0)									
Temporopolar artery (3.3)									

*The percentages refer to the number of perforators, not to the number of AChAs.

site, the intracerebral segments of the perforators continued in a dorsal and caudal direction through the brain parenchyma (Figures 3, 5, and 6).

Before their penetration, the perforating arteries were occasionally noted to give off the uncal, optic, and/or peduncular side branches (Table 1). The uncal vessels, which ranged in size from 100 μm to 160 μm (mean, 133 μm), mainly supplied the semilunar gyrus. The optic branches, which varied in size from 70 μm to 100 μm (mean, 87 μm), vascularized various portions of the optic tract. The peduncular branches (Figure 2), which measured in diameter between 80 μm and 170 μm (mean, 142 μm), supplied the rostral part of the cerebral peduncle.

Discussion

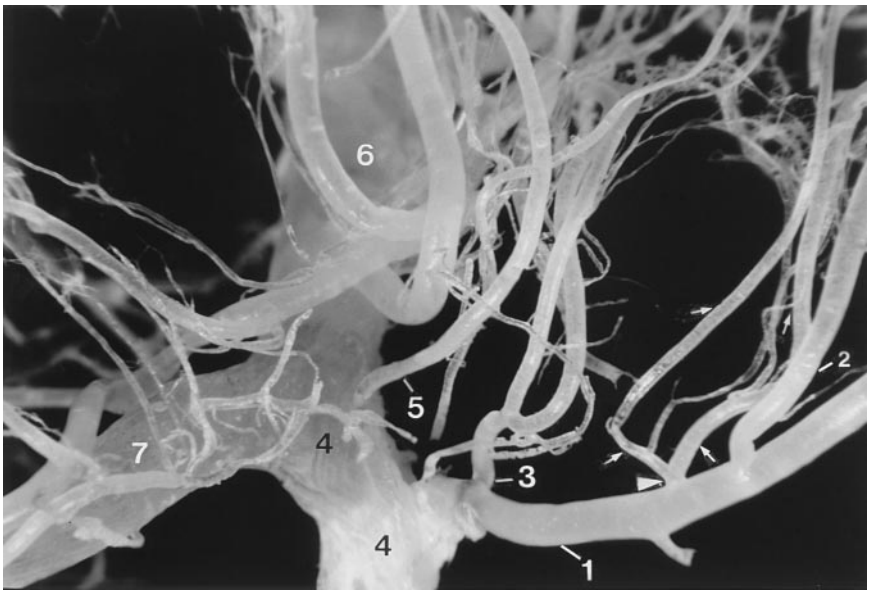
Scarce and sometimes conflicting data are present in the literature on the perforating branches of the anterior choroidal artery. Thus, the perforators have been counted from 1 to 4 per AChA [23], or 1 to 10 [26]. We found the perforators to range from 2 to 9 in number. In the cases with a smaller number of AChA perforators, these vessels were noted to arise usually by a common trunk from the ICA.

It is hard to decide whether such a trunk represents a second anterior choroidal artery or a large perforator of the ICA itself [26,32]. The important relationships between the perforators and the AChA side branches are described in the present study, as well as in our previous reports [17,19,20].

Anastomoses among the AChA perforators were not observed. However, indirect anastomoses, involving the AChA side branches which arose in common with the perforators, were noted in 25% of the cases [18].

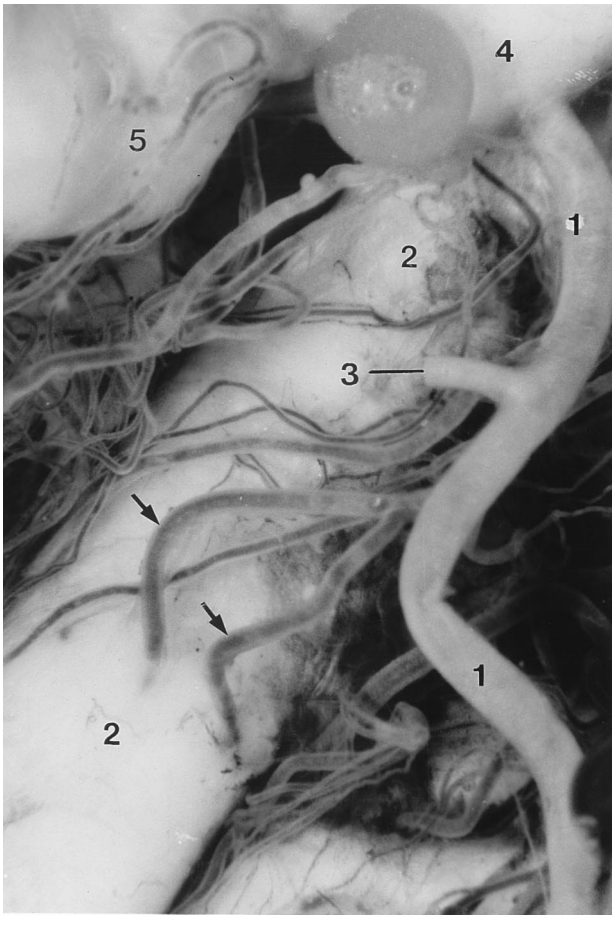
Certain vascular malformations and diseases may affect the AChA and its perforating branches, especially saccular aneurysms and microembolisms. Aneurysms of the choroid segment of the ICA, which may affect the perforators of the AChA, comprise only about 1% of all intracranial aneurysms [21]. Despite this, they are very important clinically because they usually have a broad and thin neck and hence demand extremely careful neurosurgical treatment [21,33]. Aneurysms of the AChA itself account for about 2% [33]. They usually arise from the origin site or the initial part of the AChA. These aneurysms may compress, stretch, distort, or incorporate the proximal perforators of the AChA [33].

Microemboli from aneurysms or, more often, from atheromas of the ICA or from the heart, may occlude the AChA perforators and thus cause isch-



5 Medial and slightly dorsal view of the right AChA (1). Note the short common trunk (*arrowhead*) of two smaller perforators (*arrows*). A large AChA perforator (2). The parahippocampal branch (3). The internal carotid artery (4) and its perforator (5). The middle cerebral artery (6). The anterior cerebral artery (7).

6 Medial view of the left AChA (1). Note the common trunk (2) of the uncal branch (3) and two perforators (4). The other AChA perforators (5). The internal carotid artery (6). The posterior communicating artery (7) and its premammillary perforator (8).



7 Basal view of the right AChA (1), which is slightly displaced medially. Note two perforators (*arrows*) that penetrate the optic tract (2). The parahippocampal branch (cut) (3). The internal carotid artery (4). The uncus (5).

emia in their region of supply [2,3,5,9,11,14]. Small vessel disease may also lead to occlusion of the perforating vessels and consequent ischemia [14].

The proximal perforators, which arise from the proximal one-third or -half of the AChA, supply the two medial segments of the globus pallidus, the genu of the internal capsule, and sometimes the initial part of the posterior limb of the capsule [8,11,13–15,26, 27]. On the other hand, the distal perforators, especially the capsulothalamic artery, supply the ventral and caudodorsal part of the posterior limb of the internal capsule, the retrolenticular portion of the capsule, the tail of the caudate nucleus, and the lateral thalamic nuclei. As revealed in our present study, the perforators occasionally nourish the uncus, optic tract, and rostral cerebral peduncle. They also take part in irrigation of the subthalamic nuclei [27]. Consequently, occlusion of the cisternal segment of the AChA and/or its perforators may cause hemiparesis, ataxia, hypesthesia, hemianopsia, and certain cognitive disorders [2,3,5,6,9,11,12,14].

The perforating branches of the AChA can be damaged during operations in the mediobasal temporal region, especially in patients with "psychomotor" epilepsy [23,28,30]. This is particularly true for the capsulothalamic artery, which most frequently originates just in front of the inferior horn of the lateral ventricle.

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COMMENTARY

There are two points that I consider to be the main lessons that microneurosurgeons can learn from this study:

1. The perforators from the anterior choroidal artery arise either from the whole extent of its cisternal segment or from the proximal and distal thirds of it.
2. There are no perforators arising from the plexal segment of the anterior choroidal artery demonstrated in this study. The most distal perforator (the capsulothalamic) arises outside the temporal horn, close to the lateral geniculate body. This can resolve a difficulty in surgeries involving the mesial temporal area and the temporal horn, regarding whether the coagulation of the choroid plexus may carry a risk of a motor deficit. In our own experience, coagulation of the choroid plexus of the temporal horn has never caused any motor deficit. The location of the capsulothalamic perforator might explain the motor deficit apparently "caused" by the coagulation of the choroid plexus in the temporal horn because of its proximity to the choroid plexus.

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Expect more people to keep working past 65 as they live longer and healthier lives, the social security age is nudged higher and lack of traditional pensions forces them to rely on personal savings.

Employers will ask them to stay on, at least on a part-time basis. They'll be needed because there will be fewer young workers coming along. By 2020, those near retirement will be 17% of the workforce, up from 12% in 2000. Companies will be desperate for workers with some seasoning—people who show up on time, put in a day's work and are seldom absent.

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