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Microsurgical Anatomy of the Anterior Choroidal Artery

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Summary

The anterior choroidal artery (A.ch.a.) was studied in 140 hemispheres of the human brain. In 50 specimens the artery was cannulated and perfused with acrylic resin, in 20 specimens the A.ch.a., was selectively cannulated and perfused with dye. The artery then was microsurgically dissected and photographically documented.

The site of origin of the A.ch.a., its length, outer diameter, course, branching patterns, anastomoses, and areas of supply was recorded. The surgical and diagnostic significance of the A.ch.a. and its importance during surgical procedures are discussed.

Keywords: Anterior choroidal artery; anatomical vascular perfusion; selective amygdalo-hippocampectomy; temporo-medial region.

Introduction

Vicq d'Azur (1786)[57] was the first to recognize choroidal vessels of the lateral ventricle. In the past century extensive anatomical studies of choroidal arteries, dealing with its course and supply area, have been reported by Heubner (1872)[21], Duret (1874)[12], Kolisko (1891)[27], and Beevor (1908)[3]. These results were based on data derived either from formalin-fixed brains or from the use of perfusion techniques[1, 3, 8, 10, 21, 24, 25].

The increasing use of surgical magnification for operations in the territory of the anterior choroidal artery (A.ch.a.), for instance in epileptogenic lesions in the amygdalo-hippocampal area (Yaşargil 1985)[38, 61, 62, 65], has created a need for detailed knowledge of their microvascular relationship at the level of the temporo-medial region and the lateral mesencephalon[22, 26, 39, 45, 46, 47].

The available anatomical information, however, is insufficient, especially because of the absence of selective perfusion of the A.ch.a. in operative situations.

The present study has been undertaken to provide a microsurgical description of the course of the A.ch.a. and to analyse their supply of deep-seated brain structures.

Material and Methods

Seventy human brains (140 cerebral hemispheres), free of central nervous system disease, were obtained at routine autopsy 6–12 hours post mortem. The individual's age had a mean range of 59 years. The specimens were immersed in Ringer's solution and the internal carotid and vertebral arteries were cannulated with polyethylene catheters.

In 50 specimens the arteries were flushed with 500 ml warm saline, perfused with acrylic resin (Technovit 1000; Fa. Kulzer GmbH, Frankfurt/M—FRG) and then fixed during 12 hours in a 2% formalin solution. This short fixation time produced a nearly normal consistence of cerebral parenchyma, allowing simulation of the intraoperative conditions in opening subarachnoidal cisterns and ventricular cavities.

In 20 specimins the A.ch.a. was selectively cannulated with 22 G polyethylene catheters and perfused with dye (Biodur-20; Fa. Biodur GmbH, Heidelberg—FRG) under controlled manual pressure until filling of the uncal and parahippocampal areas was evident[5, 10, 24, 31, 49].

The dissections were performed with microsurgical instruments using a Zeiss OPMI surgical microscope with a OM-Olympus photographic attachment. In every specimen, we recorded the site of origin of the A.ch.a., its length, outer diameter, course, branching pattern, and anastomoses with branches of the posterior communicating and posterior choroidal arteries. Detailed drawings of the typical findings and photographs of the more significant anatomical preparations were taken.

The supply of deep-seated structures through the A.ch.a. was analysed by cross-sections in 20 selective injected specimens.

Results and Discussion

The anterior choroidal artery (A.ch.a.) arises from the infero-lateral wall of the internal carotid artery and 3.2 mm (1.1–5.9 mm) distal to the posterior communicating artery and 5.2 mm (2.2–7.0 mm) proximal to the carotid bifurcation (Tables 1 and 2).

In 153 arteries (133 single, 7 double and 2 triple) a mean diameter of 0.9 mm (range 0.4–1.1 mm) was found when measured at their origin. Similar mea-

Table 1. *Origin of the Anterior Choroidal Artery*

Publication			Origin of the anterior choroidal artery				Technique of injection
Author	Year	N	I.C.A.	Bifurcation	M.C.A.	P.Co.A.	
Kolisko	1871	–	most				as described
Beevor	1907	174	100%	–	–	–	carmeine oil, selective gelatine
Cavatorti	1907	100	41.5%	–	58.5%	–	–
Carpenter	1954	60	76.6%	3.3%	11.7%	6.7%	no injection
Mounier/Kuhn	1955	20	100%	–	–	–	?
Otomo	1965	778	99.2%	0.4%	–	0.4%	?
Herman	1966	44	85%	7%	8%	–	methylene blue
Furlani	1973	100	–	–	–	–	94% gelatine, 6% neoprene, selective
Saeki/Rhoton	1977	100	100%	–	–	–	?
Rhoton/Fujii	1979	50	98%	–	–	2%	latex/acryl
Lanz/Wachsmuth*	1979						?
Lang*	1981		96%	–	–	2%	?
Grand	1980	36	100%	–	–	–	no injection
Rhoton/Gibo	1981	50	100%	–	–	–	latex/acryl
Present study	1987	140	97.5%	–	–	2.5%	biodur/amipaque selective

* Same material.

surements were reported by Rhoton (1979) and Yaşargil (1984)[45, 66] in unperfused specimens, respectively in vivo. Although choroidal vessels originating form the middle cerebral artery were reported by several authors (Carpenter 1974, Hermann 1966, Galimbert 1986)[8, 12, 31], in the present series of 140 hemispheres the A.ch.a. originated from the internal carotid artery in all but one case (posterior communicating artery). Our findings agree with the observations of Yaşargil (1984)[66] based upon 200 brain specimens and over 2,000 microsurgical operations. In our opinion the assumption of an origin of the A.ch.a. from the middle cerebral artery results from a false interpretation of the uncal artery, which may originate laterally from the proximal M_1-segment[8, 22, 31, 36, 51]. When precisely dissected this vessel is found to penetrate the uncal area as a terminal branch (11 cases in the present series) (Figs. 1 and 2).

In 8% of the specimens we found 1–3 small arteries (0.4–0.7 mm) arising from the infero-lateral carotid wall proximal to the origin of the A.ch.a.. These branches were also reported by Carpenter (10%)[8] and Rhoton (32%)[45] as supplying the medio-basal temporal lobe, optic tract and the posterior perforated substance[2, 7, 8, 9, 11, 14, 17, 31, 36].

In our material, however, they regulary reach the proximal optic tract and the posterior perforated substance without participating in the supply of the medio-basal temporal lobe.

The A.ch.a. occured as a single vessel in 89% of our preparations, according to Saeki and Rhoton in 96%[48]. In the present series we observed two choroidal vessels in seven specimens, and three vessels with a typical course in four specimens. In contrast Yaşargil (1984)[66] encountered 2–4 independent choroidal vessels in 30% of his cases. This discrepancy may possibly be explained by the different interpretation of the infero-lateral carotid branches arising distally to the origin of the A.ch.a. Most of these arteries are quite variable in size and branch early to penetrate the uncal area[1, 6, 13, 17, 18, 21, 22, 52].

We define as anterior choroidal arteries only such vessels which run in the crural cistern and are directed towards the optic tract or cross it. The main course of the A.ch.a. in the carotid and crural cisterns follows the direction of the optic tract, crossing it proximally and distally from lateral to medial and from medial to lateral, respectively (Figs. 1 and 3).

Several *classifications* have been used for the A.ch.a. Goldberg and Rhoton divide it into a cisternal segment, extending from its origin to the choroidal fissure and a plexal segment entering the choroidal fissure and penetrating the choroidal plexus of the temporal horn[17, 29, 45]. We prefer to divide the A.ch.a. into 3 topographical segments related to the surgical areas of interest, *i.e.* the carotid cistern, the crural cistern, and the ventricular space (Figs. 1, 4, and 8).

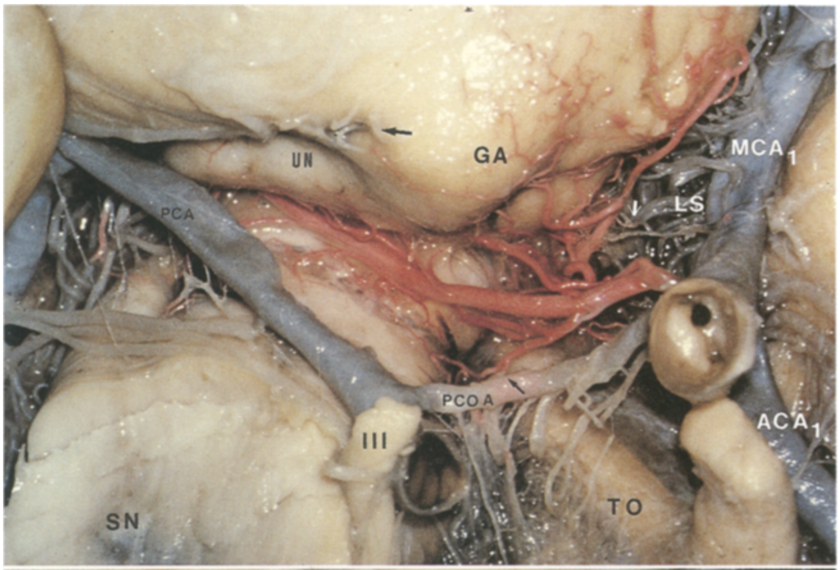

Fig. 1. Basal view of the right hemisphere into the ambient and vallecular cistern. Visualization of the cisternal segment of the A.ch.a. (6 ×). The first branch, which arises from the A.ch.a. represents the supplying group I, supplying the temporal pole and the parahippocampal gyrus/uncus.The little white arrow in the upper right part indicates a small anastomosis of this branch to a lenticulostriate artery, which is originating from the MCA. In front an anastomosis between the A.ch.a. and the PCOA (arrow). The black arrow in the upper middle part of the figure is demonstrating a branch of the PCA (rami hippocampales Aa. cerebri posterioris), running into the hippocampal sulcus. *MCA* middle cerebral artery, *ACA* anterior cerebral artery, *SN* substantia nigra, *LS* lenticulostriate arteries, *GA* ambient gyrus, *UN* uncus, *TO* optic tract, *III* oculomotor nerve, *PCOA* posterior communicating artery

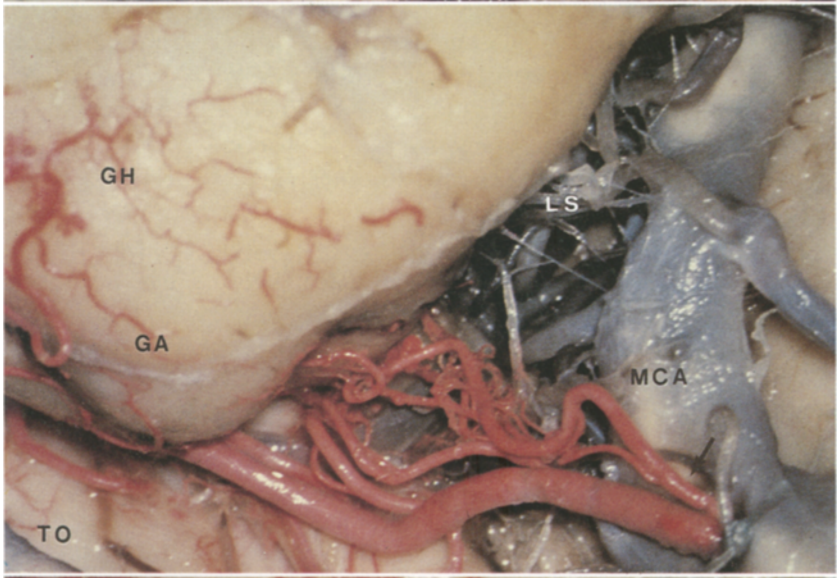

Fig. 2. Basal view, right hemisphere: area of the ambient cistern and vallecular cistern (10 ×). The arrow demonstrates the first supplying group. *GH* parahippocampal gyrus, *TO* optic tract, *MCA* middle cerebral artery, *LS* lenticulostriate arteries, *GA* ambient gyrus

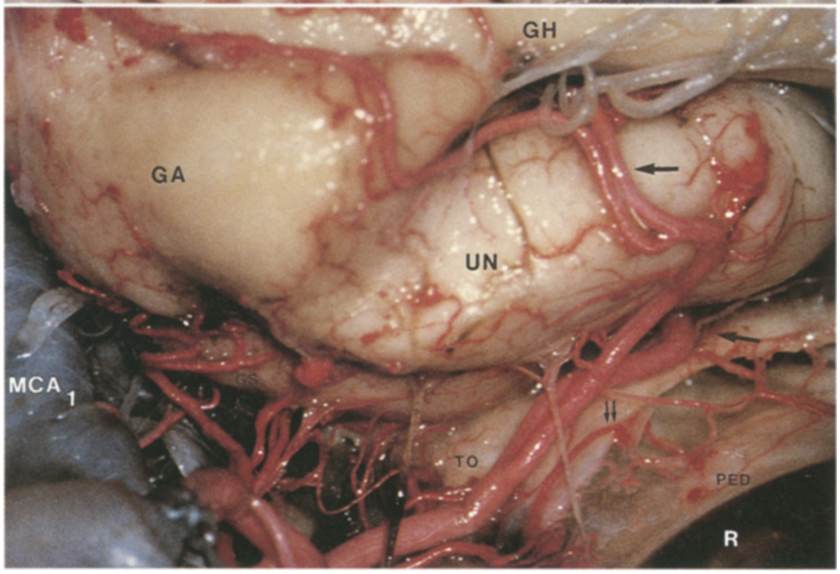

Fig. 3. Basal view of the uncal/parahippocampal region, left hemisphere (10 ×). A prominent branch (upper arrow), which originates from the second 1/3 of the A.ch.a., is running to hippocampal sulcus. Branches from the PCA running to the hippocampal sulcus and an anastomosis between the A.ch.a. and the MCA can be seen on the left part of the figure. The A.ch.a. enters the inferior horn of the lateral ventricle through the choroidal fissure (lower arrow). The second supplying group is demonstrated by double arrows. *PED* cerebral peduncle, *R* retractor, *MCA* middle cerebral artery, *GS* semilunar gyrus

Table 2. *Diameters and Distances*

Diameter of the anterior choroidal artery	1.24 mm	(0.4–3.4 mm)	(N = 42)
Diameter of the posterior communicating artery	1.15 mm	(0.4–3.3 mm)	(N = 42)
Distance anterior choroidal artery to posterior communicating artery	3.2 mm	(1.1–5.9 mm)	(N = 42)
Distance anterior choroidal artery to bifurcation of the internal carotid artery	5.2 mm	(2.2–7.0 mm)	(N = 42)

The *first segment of the A.ch.a.* runs postero-medially in the carotid cistern to reach the lateral optic tract. In 75% of our specimens it diverges from the main direction of the posterior communicating artery to cross the optic tract or runs over it to reach the peduncular area. A strong lateral branch arises from the main choroidal trunk 1–4 mm distal to its origin in 97% of the hemispheres (Fig. 2). This artery penetrates the uncal area and divides into 3–5 tiny branches supplying the head of the hippocampus. We observe a reciprocal relationship between the uncal vessels arising from the internal carodit and middle cerebral arteries and the unco-hippocampal branches of the A.ch.a. in its first segment. When uncal arteries were lacking, the A.ch.a. supplied the unco-hippocampal area with a single larger branch. In cases with developed uncal arteries, 1–4 tiny branches from the proximal A.ch.a. could be observed. In most of the present cases an early hippocampal branch is found with a frequency of 87%. It may be an important landmark for the identification of the optic tract, because it originates 2—3 mm proximal to its crossing-point with the A.ch.a. (Figs. 3 and 4). Anastomoses with the posterior communicating artery are encountered in 14% of the specimens. In two hemispheres we also observed tiny anastomotic branches with the internal carotid branches located between the origin of the posterior communicating and the choroidal artery (Fig. 1).

The *second segment of the A.ch.a.* runs in the crural cistern medially from the optic tract between the medio-basal limbic structures and the cerebral peduncle to reach the lateral geniculate body (Figs. 6 and 7).

Several authors have studied the branching patterns and the distribution of the A.ch.a. and its peduncular course[9, 17, 22, 31, 45]. Rhoton *et al.* (1979)[45] described a) superior branches supplying the anterior and posterior perforate substance, the optic tract, the origin of the optic radiations, the medial globus pallidus and the posterior limb of the internal capsule; b) infero-lateral branches to the amygdaloid body, the anterior hippocampus and the fascia dentata and c) medial branches entering the cerebral peduncle and the lateral geniculate body. Goldberg (1974)[17] further devided the

Table 3. *Anastomoses of the Anterior Choroidal Artery in 140 Hemispheres*

A.ch.a. with posterior cerebral artery	51%
A.ch.a. with middle cerebral artery	12%
A.ch.a. with posterior communicating artery	14%
A.ch.a. with internal carotid artery	5%

medial vascular group into proximal branches to the substantia nigra, to parts of the red nucleus, subthalamus, and to the ventro-lateral thalamic nuclei and into distal branches supplying the antero-lateral geniculate body. In Abbie's[1, 2] work the artery was reported to supply the inferior part of the optic tract, the posterior two-third of the internal capsule, the origin of the optic radiations, the medial globus pallidus as well as the anterior cerebral peduncle. Additionally, it may participate in the supply of the head of the caudate nucleus, amygdaloid body, substantia nigra, red nucleus, subthalamic body and ventro-lateral thalamic nucleus[1, 2, 7, 8, 12, 15, 27, 32, 33, 36, 37, 41, 44, 45, 48, 50, 54].

In our specimens with a single A.ch.a., a proximal superior branch regulary enters the hippocampal sulcus to supply the anterior hippocampus, the fascia dentata, the tail of the caudate nucleus and the postero-medial amygdaloid body (Figs. 3, 4, and 5). In cases, in which more than one A.ch.a. are present, we observed 2–3 tiny branches to the hippocampal and dentate gyri. According to other authors[20, 31, 35, 38, 52, 65] we observed a reciprocal relationship between the hippocampal branches of the anterior choroidal and the posterior cerebral arteries. In absence of an hippocampal vessel arising from the P_1- or P_2-segment of the posterior cerebral artery, the A.ch.a. also supplies the middle portion and the tail of the hippocampus.

Superior branches arising from the distal A.ch.a. are present in every specimen. A supply of the posterior limb of the internal capsule and the lateral geniculate body by these arteries was proved in 61% of cases by cross-sections (Figs. 5 and 7). In our material, two patterns of origin of the optic branches from the A.ch.a. have been observed. Most frequently, in 60% of our

Table 4. *Structures Supplied by the Anterior Choroidal Artery in 140 Hemispheres*

Anterior part of the hippocampal gyrus	20%	1× + + +/ 2.5%	2× + + +
(semilunar gyrus/ambient gyrus/temporal pole)	25%	1× + + / 2.5%	2× + +
	12%	1× + /25%	2× + /7% 2× +
	20%	∅	
Uncus/hippocampal sulcus inferior part of the hippocampal gyrus	41%	1× + + +/ 2.5%	2× + + +
	32%	1× + + /10%	2× + +
	34%	1× + /22%	2× +
	2.5%	∅	
Optic tract medial and/lateral branches/perforating branches to	25%	1× + + +/ 7%	2× + + +
corpus pallidum/amygdala	27%	1× + + /25%	2× + + /
			15% 2× + +
	46%	1× + /25%	2× +
	12%	∅	
Optic tract	2.5%	1× + +/ 2.5%	2× + +
	12%	1× + /10%	2× +
	50%	1–10× (+)	
	20%	∅	
Cerebral peduncle	2.5%	1× + + +	
	31%	1–3× + +	
	68%	1–7× +/10%	(+)
	2.5%	∅	
Lateral geniculate body	2.5%	+ + +	
	32%	+ +	
	22%	+	
Perforating branches to deep structures	17%	1× + + +/10%	1× + + +
(internal capsulae, optic radiation)	34%	1–3× + +	
	10%	1–2× +	
	39%	∅	

+ + + = very large branches, + + = large branches, + = moderate branches, (+) = thin branches.

specimens, 4–6 small vessels arise directly from the infero-lateral wall of the A.ch.a. In 40% of the cases we observe two stem arteries, that devide early into numerous tiny branches to the optic tract and proximal optic radiations (Fig. 6). This anatomical arrangement occurs more often when the A.ch.a. followed laterally the optic tract or ran over it (19 of 35 cases).

Perforating vessels through the optic tract are encountered in every specimen and consist of 1–4 short branches, which arise proximally from the infero-lateral wall of the A.ch.a. These particular findings are shown in Fig. 9. These terminal arteries supply the antero-medial two-thirds of the globus pallidus (100% of cases) and the medial amygdaloid body (68%). The A.ch.a. gave origin from three up to nine medial branches in one hemisphere (average 5.7). The vessels passing to the antero-lateral cerebral peduncle show a shorter course than those reaching the posterior peduncular areas. This vascular group supplies the antero-lateral third of the mesencephalon and occasionally participated in supplying the substantive nigra, red nucleus, subthalamus and ventrolateral thalamic nucleus (Table 4; Fig. 5).

In accordance with Galatius-Jensen (1961)[16] we observed anastomoses with the posterior choroidal arteries in 32% of the cases (Figs. 4 and 8). They occur most frequently with the anterior branch when more than one posterior choroidal artery was present[4, 11, 13, 16, 48]. In contrast Carpenter[8] encountered anastomoses between these vascular groups in 93% of the cases. In this study no definite anastomoses were found between the A.ch.a. and the thalamo-geniculate branches of the posterior cerebral artery (Table 3).

The *third segment of the A.ch.a.* runs through the wing of the ambient cistern and crosses again the optic tract from medial to lateral at the level of the anterior part of the lateral geniculate body. The number of branches to the lateral geniculate body is usually in-

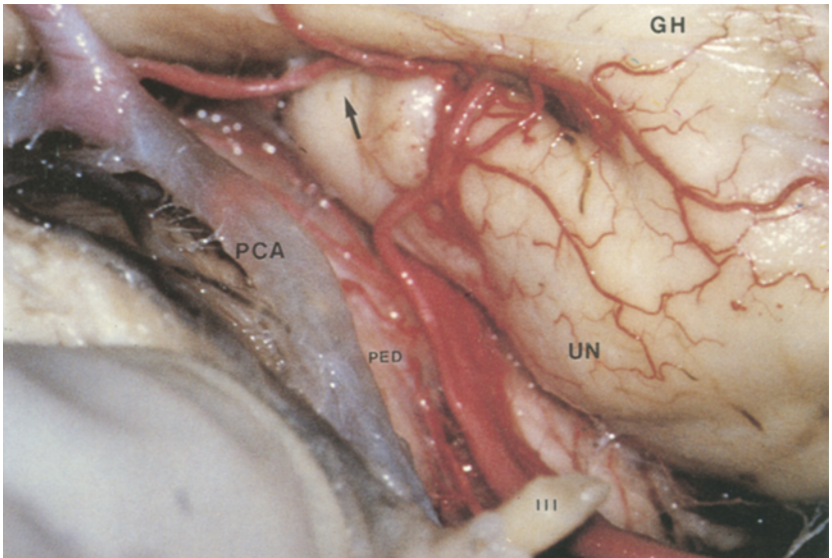

Fig. 4. Basal view of the uncal/parahippocampal region, left hemisphere (10×). A prominent branch, arising from the second 1/3 of the A.ch.a., running to the hippocampal sulcus. This branch forms a large anastomosis with a hippocampal branch of the PCA (arrow). *UN* uncus, *GH* parahippocampal gyrus, *PED* cerebral peduncle, *III* oculomotor nerve, *PCA* posterior cerebral artery

Fig. 5. Axial section at the level of the anterior commissure showing the deep structures supplied by the A.ch.a. (16×). *4* inner part of the globus pallidus, *6* lateral geniculate body, *7* internal capsule (crus posterius, pars retrolentiformis), *8* nucleus reticularis thalami. Other structures: *1* caput nuclei caudati, *2* putamen, *3* lateral part of the globus pallidus, *5* anterior commissure

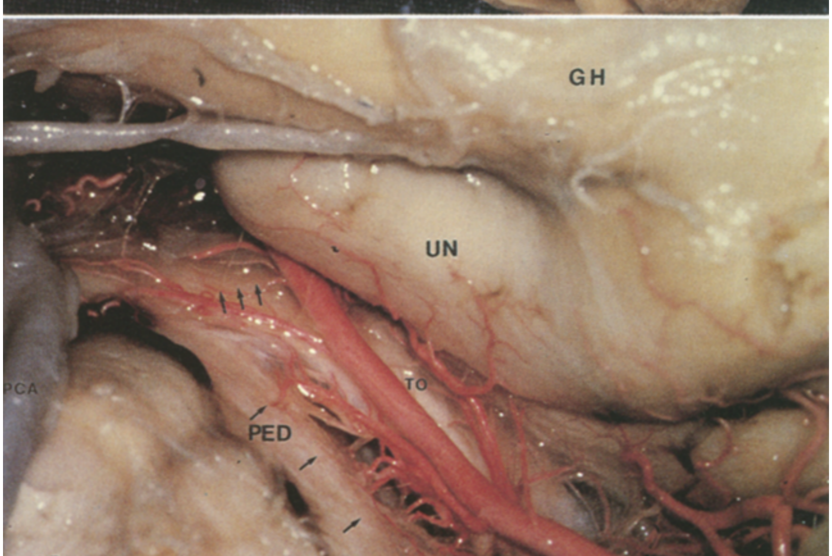

Fig. 6. Basal view of the uncal/parahippocampal region, left hemisphere (10×) (ambient cistern). The small arrows demonstrate the supplying branches to the cerebral peduncle. Three small arrows are showing the region of the lateral geniculate body. Anastomosis with the PCA can be clearly seen in this region. *BS* brainstem, *GH* parahippocampal gyrus, *UN* uncus, *PED* cerebral peduncle, *PCA* posterior cerebral artery

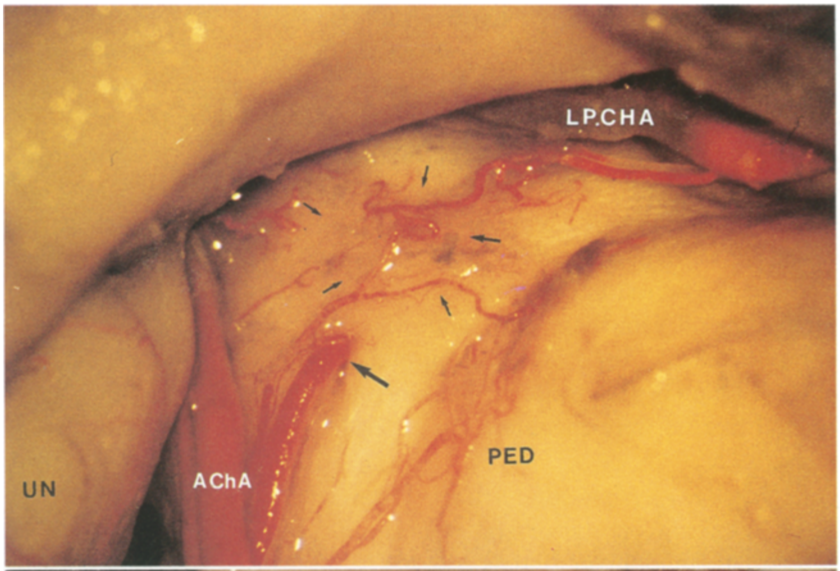

Fig. 7. Choroidal fissure (magnification 25 ×). Very thin anastomosis between the A.ch.a. and the LP.CH.A. on the surface of the lateral geniculate body (arrows). Two branches of the A.CH.A., one of them very and one moderately large, penetrate the brain substance (big arrow). *UN* uncus, *LP.CHA* postero-lateral choroidal artery, *PED* cerebral peduncle, *AChA* anterior choroidal artery

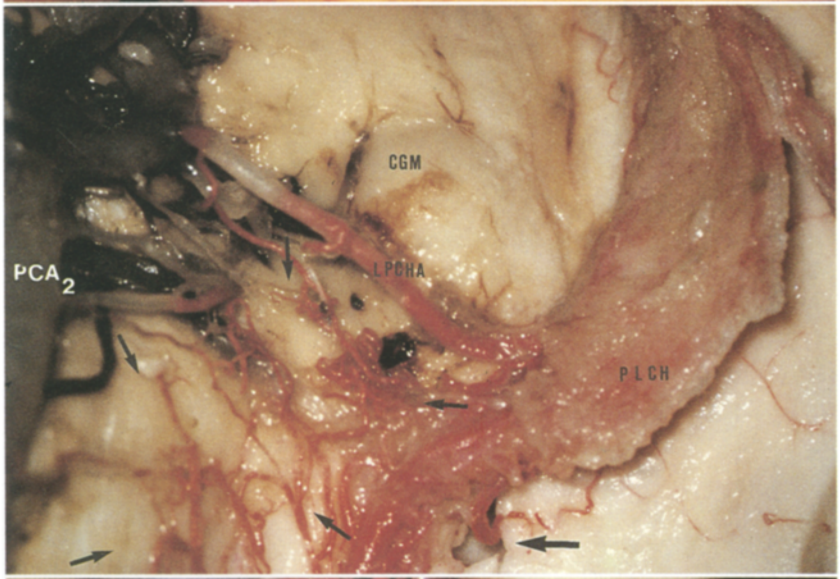

Fig. 8. Opened temporal horn of the lateral ventricle, right hemisphere (10 ×), showing the choroid plexus with the supplying arteries (LP.CHA and A.ch.a.). Multiple anastomoses between both choroidal arteries are demonstrated. The blood supply of the lateral geniculate body is derived from both choroidal arteries, a net of fine anastomoses is demonstrated by five arrows. *PLCH* choroid plexus, *LPHCA* postero-lateral choroidal artery, *CGM* medial geniculate body, *PCA* posterior cerebral artery, big arrow = penetrating branch to the internal capsule

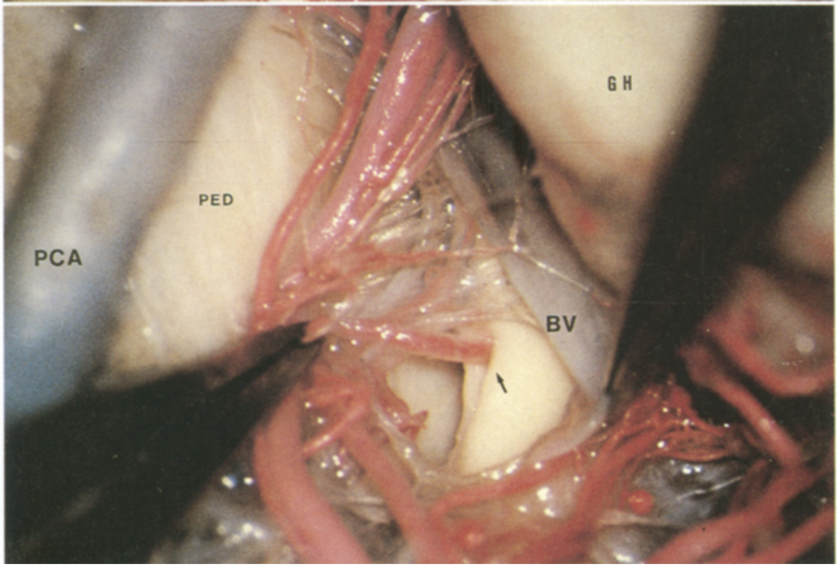

Fig. 9. A branch which is penetrating the optic tract in its middle third and supplied the anterior two-thirds of the corpus pallidum, the optic tract and the amygdala (arrow) (25 ×). *BV* basal vein, *PED* cerebral peduncle, *GH* parahippocampal gyrus, *PCA* posterior cerebral artery

versely proportional to the number of vessels to the cerebral peduncle. Very large geniculate branches can be found under the operating microscope in 2.5% of the cases (Table 4). The main A.ch.a. then penetrates the choroidal fissure to reach the choroid plexus of the temporal horn (Fig. 3). Although some branches of the A.ch.a. anastomose with branches of the posterior communicating, posterior cerebral and posterior choroidal arteries, the richest anastomotic network was located on the lateral geniculate body and especially on the choroid plexus (Figs. 7 and 8). Multiple anastomoses at the junction between the choroidal and the transverse cerebal fissures were encoutered in 51% of the specimens.

A balance of perfusion-territories between the anterior choroidal, posterior communicating, posterior cerebral and middle cerebral arteries has been reported by several authors[1, 2, 6–8, 16, 19, 22, 23, 30, 34, 39, 40, 42, 45, 64]. Not infrequently the posterior communicating artery is small or hypoplastic. In this case one can expect to find a reciprocally enlarged A.ch.a., supplying the genu and the anterior one-third of the internal capsule. On the other hand, if the A.ch.a. is hypoplastic, the arterial distribution area of the posterior communicating artery may include the posterior limb of the internal capsula[2, 15, 27, 53, 55, 56, 63].

Blackburn (1907)[4] dissected two specimens, in which the vascular territory of the A.ch.a. was enlarged so that a supply of large parts of temporal and occipitobasal areas took place. As previoulsy reported (Hussein and Renella 1986)[23]; we encountered a similar anatomical arrangement in one specimen. A hypoplastic posterior cerebral artery was compensated for by the A.ch.a., supplying the parahippocampal, medial and laterial occipito-temporal and inferior occipital gyri[8, 9, 14, 17, 43, 46, 65].

The reciprocal relationship between the different vascular territories as well as the extensive collateral network are responsible for the inconstant and unpredictable deficit following surgical occlusion of the A.ch.a.

Occlusion of the A.ch.a. in its first segment may lead to a contralateral hemiparesis and hemianopsia as described by Foix (1925)[14, 43, 53]. Transient loss of consciousness as well as extrapyramidal signs may also occur following an ischaemic lesion in the pallidal area (Rhoton *et al.* 1979)[45]. On the contrary occlusion of the A.ch.a. at the level of the choroidal fissure may be well tolerated because there are rich anastomoses between the A.ch.a. and the postero-lateral choroidal artery in the inferior horn of the lateral ventricle. Selective occlusion of the third segment may re required in intraventricular angiomas and[34] of meningiomas. Neurological deficits following this procedure are not reported. It has to be emphasized that the A.ch.a. should be spared in the intracisternal part because anastomoses cannot be surly demonstrated with certainty in preoperative angiograms or directly visualized early in the procedure.

In our opinion the distal hippocampal branch (Figs. 3 and 4) is a useful mediobasal landmark for the transventricular microsurgical resection of the hippocampus, as described by Yaşargil[65].

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