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Accessory middle cerebral artery: is it a variant form of the recurrent artery of Heubner?

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Accessory Middle Cerebral Artery:
Is It a Variant Form of the Recurrent Artery of Heubner?

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Fourteen accessory middle cerebral arteries demonstrated on angiography were reviewed relative to the pertinent literature. The anomalous vessel follows a fairly constant pattern in terms of origin, course, and distribution, and it frequently gives rise to basal perforating arteries. It is suggested that the vessel represents a persistent anastomosis between the anterior and middle cerebral arteries over the tuberculum olfactorium, the anastomosis being a predecessor of the recurrent artery of Heubner in phylogenetic development. Among various descendants of the anastomotic channels could be included both the normal recurrent artery of Heubner and the accessory middle cerebral artery, with or without basal perforating arteries.

We believe the simultaneous presence of the recurrent artery of Heubner and the accessory middle cerebral artery on one side may represent the persistence of two anastomoses, one as the recurrent artery of Heubner and the other as the accessory middle cerebral artery; this is similar to the situation of duplication of the recurrent artery of Heubner.

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Ever since it was first proposed by Teal et al. [1] in 1973, the term *accessory middle cerebral artery* (accessory MCA) has generally been restricted to the anomalous artery that arises from the anterior cerebral artery (ACA) to supply the cortex in the distribution of the middle cerebral artery (MCA); that branch arising from the internal carotid artery has been called *duplication of the MCA*.

Accessory MCA was first used by Crompton [2] in 1962 to describe a vessel that passes into the sylvian fissure with the MCA, supplying the cortex in the distribution of this artery; the term included both the duplication and the accessory MCA as currently defined. Of 347 dissected brains, Crompton found 10 duplications of the MCA (2.9%) and one accessory MCA (0.3%). In 1964, Jain [3] dissected 300 brains and found eight accessory MCAs (2.7%) and two duplications of the MCA (0.7%).

Handa et al. [4, 5] were the first to demonstrate the accessory MCA on angiography, and they suggested that the anomalous vessel represents hypertrophy of the recurrent artery of Heubner (RAH). This assumption was disputed by Stabler [6] and Teal et al. [1]. Teal et al. disagreed with Handa et al. on the basis that (1) perforating arteries have only occasionally been shown to arise from this vessel, (2) the RAH was repeatedly demonstrated in the presence of the accessory MCA, and (3) the RAH enters the anterior perforated substance while the accessory MCA clearly courses lateral to this point. The third point is not a valid argument against the theory of a hypertrophic RAH because hypertrophic changes may naturally cause outward growth of the RAH toward the sylvian fissure. The first and second reasons have been so persuasive that some articles [7,8] have appeared supporting the idea of Teal et al. Other authors [9–11] have not provided their own conclusions, but only reiterated the ideas of Handa et al. and Teal et al. No alternative explanation has been suggested for the formation of this anomalous artery other than the hypertrophic change of the RAH described above.

We believe the question remains open concerning the relationship between the accessory MCA and the RAH, and we suspect they share some common, if not identical, developmental mechanism. This idea prompted us to review our cases of accessory MCA demonstrated on angiography and the relevant literature.

Materials and Methods

We reviewed 400 consecutive carotid angiograms in 200 patients, all of which were obtained stereoscopically. The anomalous artery was identified in eight patients (4%), a single accessory MCA in seven, and paired accessory MCAs in one (2.25% of hemispheres). One patient had duplication of the MCA on the opposite side and another had anomalous temporal arteries bilaterally. Five more accessory MCAs were collected (some of the angiograms were not stereoscopic). In all, we reviewed angiographic findings in a total of 14 accessory MCAs; in all but one study, subtraction was used to identify their origin, course, and distribution, focusing especially on whether the vessel had perforators arising from it and whether the RAH was present in addition to the accessory MCA.

Results

Every accessory MCA in our series was seen on angiography to originate from the ACA near the level of the anterior communicating artery, to pass laterally through the cistern in the region of the anterior perforated substance, and to go to the insular region, finally supplying the cortex in the distribution of the MCA. Although the extent of the distribution was not identified accurately in all cases on angiography, it seemed to vary to some degree according to the vessel's diameter, but all of them appeared to supply the insula, the lateral orbital surface, and the lateral aspect of the frontal lobe.

Perforating arteries were found to arise from six of 14 accessory MCAs (Figs. 1–3), while no perforators were seen to arise from three accessory MCAs (Fig. 4). When this vessel was opacified on the opposite carotid angiogram, it was not difficult to decide whether or not it had a perforating artery (Figs. 1, 3, and 4). It was difficult, however, when the anomalous vessel was opacified only on carotid angiograms on the same side, especially without stereoscopic observation (Fig. 2). In the other five cases, it was not determined whether
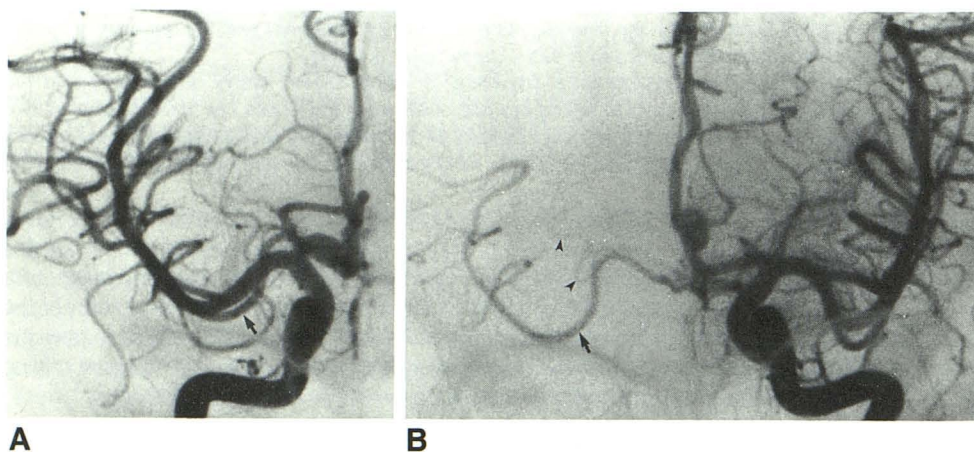

A   B

Fig. 1.—Accessory middle cerebral artery arborizing basal perforating artery.
A, Right carotid angiogram shows accessory middle cerebral artery (*arrow*), which is superimposed on horizontal portions of anterior and middle cerebral arteries. Whether or not accessory middle cerebral artery arborizes basal perforators could not be determined from this view.
B, Left carotid angiogram shows accessory middle cerebral artery (*arrow*) on opposite side. Anomalous vessel is clearly shown to give rise to basal perforator (*arrowheads*) at anterior perforated substance and to extend to insula and then to lateral surface of frontal lobe on right side.
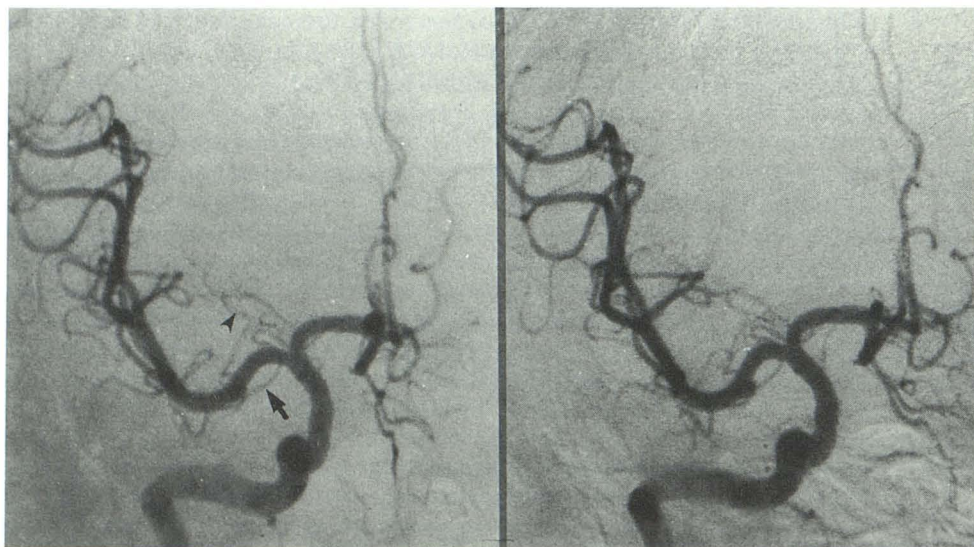

Fig. 2.—Accessory middle cerebral artery arborizing basal perforating artery. Stereoscopic right carotid angiogram shows barely visible basal perforator (*arrowhead*) arising from bending portion of accessory middle cerebral artery (*arrow*). Occlusion of distal portion of right anterior cerebral artery is also noted. Anomalous vessel on opposite side did not fill during left carotid angiogram (not shown).

Fig. 3.—Accessory middle cerebral artery arborizing basal perforating artery, incidentally noted in patient with anterior clinoid meningioma on left.

A and *B*, Right (*A*) and left (*B*) carotid angiograms. On left carotid angiogram, dense tumor vascularity is seen displacing supraclinoid portion of internal carotid artery medially. Although accessory middle cerebral artery (*arrows*) is markedly elevated by mass, it is not easy to identify accessory middle cerebral artery without stereoscopic observation. On right carotid angiogram, accessory middle cerebral artery on contralateral side is clearly depicted to originate two perforators (*arrowheads*) on its way to terminal distribution area in lateral aspect of frontal lobe.
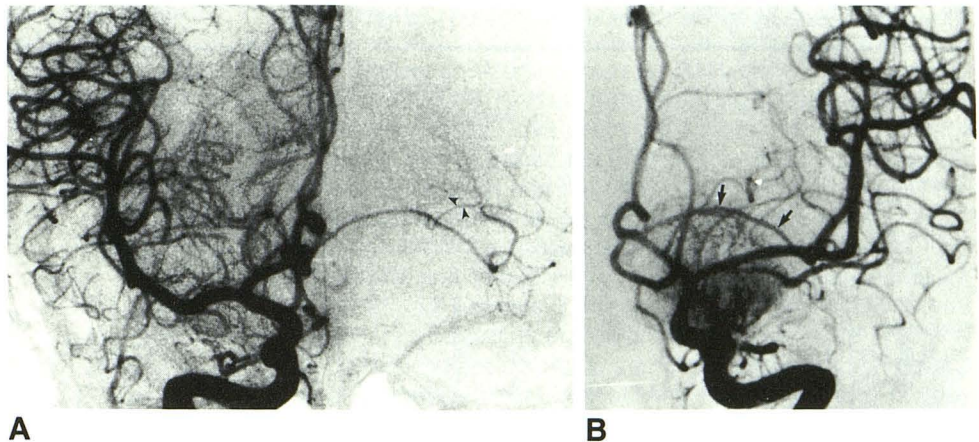

A

B

Fig. 4.—Separate origin of accessory middle cerebral artery and recurrent artery of Heubner in patient with giant aneurysm arising from middle cerebral artery. Accessory middle cerebral artery (*arrows*) and recurrent artery of Heubner (*arrowheads*) are seen to arise from anterior cerebral artery, both at level of anterior communicating artery, although they may share a short common stem at the origin.
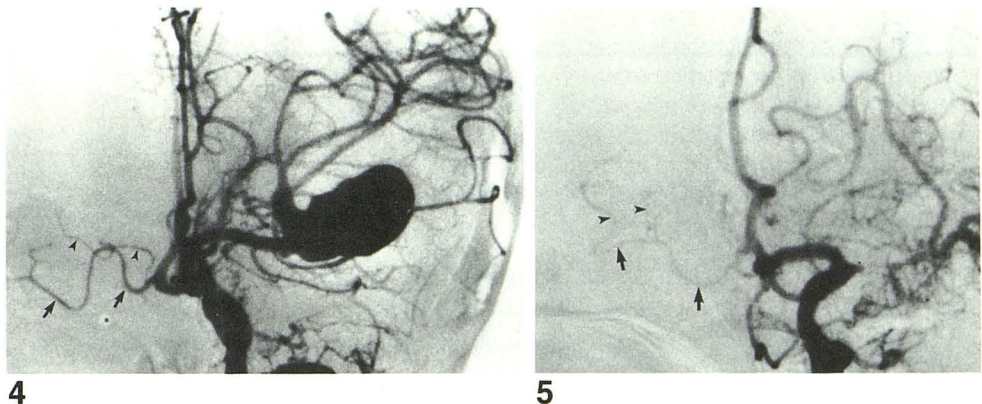
Fig. 5.—Normal recurrent artery of Heubner in patient with occlusion of middle cerebral artery. Normal recurrent artery of Heubner (*arrows*) is sometimes filled on carotid angiography on contralateral side. Recurrent artery of Heubner is seen to arborize two perforators upward (*arrowheads*).

4

5

perforating arteries arose only from the MCA proper or also from the accessory MCA. One accessory MCA was seen in a patient with an anterior clinoid meningioma that displaced the anomalous vessel upward (Fig. 3). The RAH was seen to arise independently from the ACA on the same side as the accessory MCA in two cases (Fig. 4), although the possibility was not ruled out that they might share a short common stem in the region of origin from the ACA trunk.

Our results on perforating arteries are given in Table 1 along with the cases found in the literature. In all, approximately 44% of accessory MCAs arborize perforating arteries, while 27% do not have perforating arteries. Independent RAHs are simultaneously present with the accessory MCAs in approximately 13% of cases.

Discussion

Although it is quite unnatural in a hemodynamic sense to detour to the terminal distribution area, nearly all accessory MCAs follow very constant courses, originating from the ACA, usually at the level of the anterior communicating artery (like the RAH); passing laterally through the cistern in the region of the anterior perforated substance; and finally supplying the insula, lateral orbital surface, and lateral aspect of the frontal lobe. This constancy suggests a certain common develop-

mental basis for the various forms of this anomalous artery. In fact, a striking similarity is seen between the RAH and the proximal part of the accessory MCA with the perforators that branch from it; this resemblance prompted us to undertake this study (compare Figs. 1 and 5). Tran-Dinh [16] also noted the morphologic similarity between them and is the only author to support the idea of Handa et al. [4] that the accessory MCA represents a variant of the RAH.

Phylogenetically, the RAH represents the one remnant of the anastomotic channels over the tuberculum olfactorium, between the ACA and the original stem of the MCA, as seen in marsupials and ungulates [17]. Because an enlarging neocortex in primates causes pyriform branches of the MCA to grow outward, the medial half of this anastomotic channel enlarges and the ACA supplies the anteromedial striate branches, while the communication with the MCA eventually disappears. Thus, the ACA eventually supplies regions once fed by the MCA via the enlarged anastomotic channel of the RAH (Fig. 6) [18].

Many anatomic studies of the proximal ACA have been published, including some on the microsurgical anatomy of the RAH. Some of those findings seem to support the phylogenetic development described above. For example, the distribution pattern of perforating sites in each group of striate arteries in the anterior perforated substance [19] appears to be compatible with the phylogenetic developmental explana-

TABLE 1: Accessory Middle Cerebral Artery (MCA) and Its Perforator

Reference	Accessory MCA	Perforator			Independent RAH
		Present	Absent	Unclear	
Crompton [2] (1962)	1	0	0	1	0
Jain [3] (1964)	8	1	7	0	1
Handa et al. [4] (1968)	2	2	0	0	0
Krayenbühl and Yasargil [12] (1968)	1	0	0	1	0
Handa et al. [5] (1970)	2	2	0	0	0
Teal et al. [1] (1973)	3	0	0	3	0
Watanabe and Togo [9] (1974)	4	2	2	0	0
Ito et al. [7] (1975)	6	1	2	3	2
Yasargil and Smith [8] (1976)	1	0	0	1	1
Waga et al. [13] (1977)	1	0	0	1	0
Ito et al. [14] (1981)	1	1	0	0	0
Umansky et al. [11] (1984)	2	2	0	0	1
Marinković et al. [15] (1986)	3	3	0	0	0
Tran-Dinh [16] (1986)	3	3	0	0	0
This study	14	6	3	5	2
Total	52	23 (44)	14 (27)	15 (29)	7 (13)

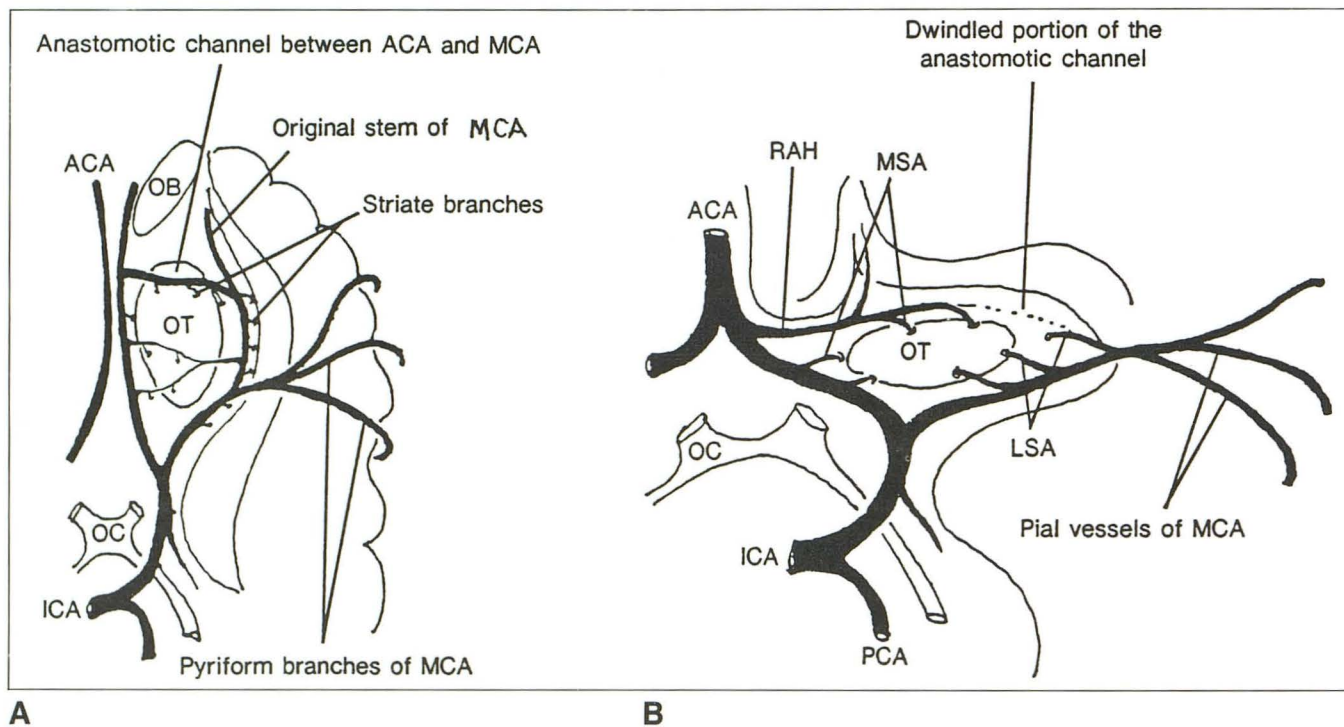Note.—RAH = recurrent artery of Heubner.

Fig. 6.—Phylogenetic development of the recurrent artery of Heubner (RAH). (Reprinted from [18], with permission.)

A, Basal surface of marsupial forebrain. Note anastomotic channels between anterior cerebral artery (ACA) and original stem of middle cerebral artery (MCA), one of which is predecessor of recurrent artery of Heubner (RAH).

B, Basal surface of primate forebrain. Continuation of anterior cerebral artery channel enlarges while that of middle cerebral artery eventually disappears, thus completing formation of recurrent artery of Heubner.

OB = olfactory bulb; OC = optic chiasm; OT = olfactory tubercle; ICA = internal carotid artery; MSA = medial striate arteries; LSA = lateral striate arteries; PCA = posterior cerebral artery.

tion that the RAH represents one remnant of some anastomotic channels (Fig. 7).

Duplication and absence of the RAH have been described [20–22]. Gomes et al. [23] reported the presence of a double RAH in 12% and its absence in only 3% of cases. In the study by Marinković et al. [15] of 66 hemispheres in cadaveric brains, a double RAH was found in 24% and even a triple RAH in 3%, but its absence was found in none. Duplication

or triplication of the RAH may represent persistence of the anastomotic channels over the tuberculum olfactorium, not inconsistent with the phylogenetic explanation. From this point of view, existence of an independent RAH on the same side as the accessory MCA (13% in our series) would not

refute the idea that they share a developmental origin. This idea is also supported by the fact that most patients with an accessory MCA do not have an RAH, since cadaveric hemispheres with no RAH are quite rare [15, 23]. The simultaneous presence of the RAH and the accessory MCA on one side may in fact represent the persistence of two anastomoses, one as the RAH and the other as the accessory MCA; this situation is similar to that of duplication of the RAH.

The RAH has frequently been described to arborize frontoorbital and olfactory branches almost consistently [15, 20, 22–25]; for example, in the microsurgical study of Gomes et al. [24], an olfactory branch of the RAH was found in 91% of 60 hemispheres. The latter vessel may represent the remnant of the original stem of the MCA in the phylogenesis. Furthermore, Kaplan and Ford [24] suggested that extracerebral anastomoses exist between the RAH and lateral striate arteries. They were observed by Gomes et al. [23] in 9% of postmortem brains, which also supports the phylogenetic explanation.

The lateral striate arteries that arise from the MCA originate either from the proximal stem or from one of the secondary vessels into which the proximal stem divides (Fig. 8A). Whether or not some lateral striate arteries arise from the secondary branches depends on how soon the major stem becomes subdivided [24]. In one-half of the hemispheres in the series of Rosner et al. [19], some lateral striate arteries arose from the secondary branches. When this occurs it is usually from the most rostrally placed branch [24].

If an extracerebral anastomosis remains between the RAH and lateral striate artery, which arises from the secondary (rostral) branch of the MCA, and the communication between the secondary branch and the major stem of the MCA disappears, the accessory MCA will be formed and give rise to
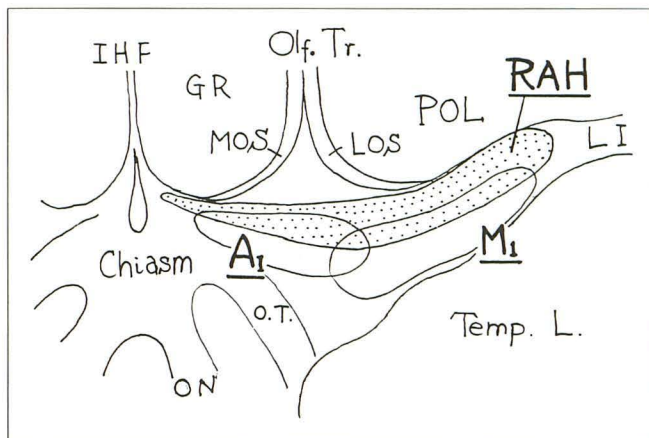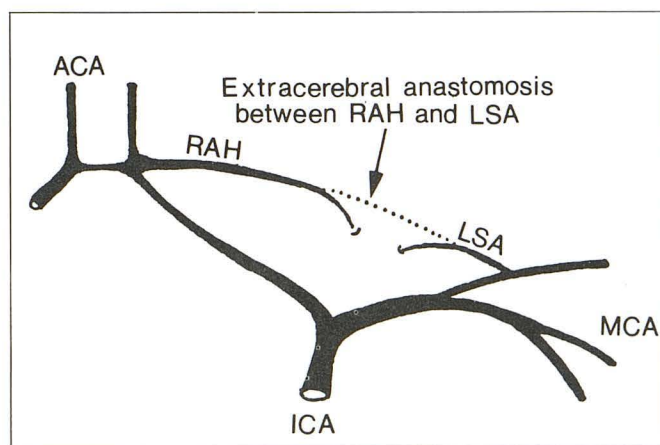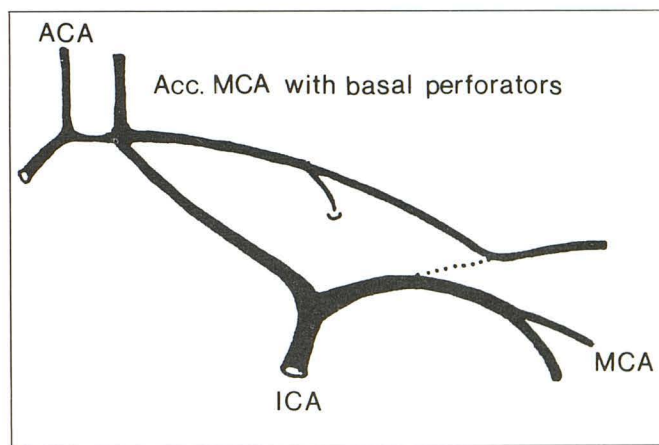

Fig. 7.—Perforation sites of basal perforating arteries in anterior perforated substance. (Adapted from [19], with permission.) Medial striate arteries, from horizontal (A1) portion of anterior cerebral artery, enter brain through posteromedial part and lateral striate arteries, from sphenoidal (M1) portion of middle cerebral artery, enter brain through posterolateral part of anterior perforated substance; branches of recurrent artery of Heubner enter full mediolateral extent but are confined predominantly to anterior half of anterior perforated substance. A1 = perforation site of perforators from A1 portion of anterior cerebral artery; GR = gyrus rectus; IHF = interhemispheric fissure; LI = limen insulae; LOS = lateral olfactory stria; M1 = perforation site of perforators from M1 portion of middle cerebral artery; MOS = medial olfactory stria; Olf. Tr. = olfactory tract; ON = optic nerve; O.T. = optic tract; POL = posterior orbital lobule; RAH = perforation site of perforators from recurrent artery of Heubner; Temp. L. = temporal lobe.

A

B

Fig. 8.—Formation of accessory middle cerebral artery (Acc. MCA) by persistence of one of the anastomotic channels between anterior (ACA) and middle (MCA) cerebral arteries over tuberculum olfactorium.

A, Normal recurrent artery of Heubner (RAH). Some lateral striate arteries (LSA) frequently arise from one of the secondary branches of the middle cerebral artery. When this occurs, it is usually from the most rostrally placed branch. An extracerebral anastomosis occasionally may be present between recurrent artery of Heubner and lateral striate artery.

B, Accessory middle cerebral artery with basal perforators. If extracerebral anastomosis remains between recurrent artery of Heubner and lateral striate artery, which arises from secondary (rostral) branch of middle cerebral artery, and communication between rostral branch and major stem of middle cerebral artery subsequently disappears, accessory middle cerebral artery will be formed that gives rise to perforators and terminates in frontal part of distribution of middle cerebral artery.
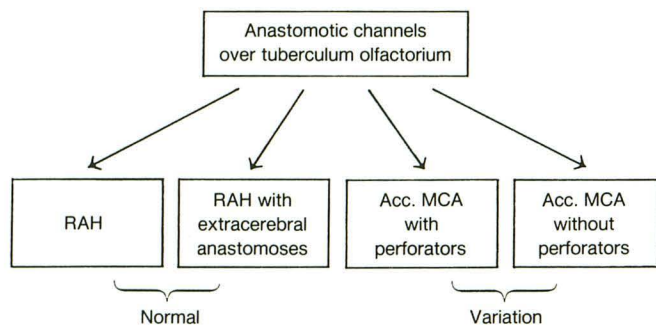
ICA = internal carotid artery.

Fig. 9.—Various descendants of anastomotic channels over tuberculum olfactorium between anterior and middle cerebral arteries. RAH = recurrent artery of Heubner; Acc. MCA = accessory middle cerebral artery.

perforators and then terminate in the frontal part of the MCA distribution (Fig. 8B). This idea is consistent with the fact that approximately 44% of accessory MCAs have been found to have perforators; but it is inconsistent with the significant number of anomalous vessels not arborizing any perforators (27%). In this regard, the anomalous vessel cannot be considered just a variant of the RAH itself, despite the striking similarity, because the RAH by definition should have basal perforators. This question could be resolved only if there were some channels without perforators among those anastomoses. Thus, the accessory MCA with or without perforating arteries could be considered a persistent form of various descendants of anastomotic channels between the ACA and MCA over the tuberculum olfactorium, one of which is also a normal predecessor of the RAH (Fig. 9).

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