Perforating branches of the middle cerebral artery

Microsurgical anatomy of their extracerebral segments

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Perforating branches of the middle cerebral artery (MCA) were examined under magnification in 50 formalin-fixed brain hemispheres. Perforating vessels varied in number from three to 18, with an average of nine. The greater the number of vessels, the smaller was their diameter. In this study, the perforating arteries were divided into medial, middle, and lateral groupings. Those in the medial group usually arose directly from the MCA main trunk close to the carotid bifurcation. There were usually three vessels in the middle group, which originated not only from the MCA trunk, but also from the MCA collateral (cortical) branches. Common stems, when present, gave rise to individual perforating vessels and occasionally to thin olfactory and insular rami. Perforating arteries in the lateral group varied from one to nine in number. In addition to an origin from the MCA trunk, they also arose from cortical branches supplying the frontal and temporal lobes. The fact that lateral perforating vessels often originated from division sites and from terminal branches of the MCA is of clinical significance, because aneurysms are more commonly located at the MCA bifurcation. Anastomoses were not found among the perforating arteries. In two specimens, a fusion between a perforating artery and the MCA trunk was noted. Since the perforating vessels are obviously end arteries, injury to them must be avoided during operations for MCA aneurysms.

KEY WORDS • perforating artery • lenticulostriate artery • middle cerebral artery • anatomical study

ANEURYSMS are often located on the proximal (M₁) segment of the middle cerebral artery (MCA).¹⁹,₂⁰,₂¹ Perforating (lenticulostriate) arteries that supply the basal ganglia and internal capsule¹⁰,₁⁴,₁₆,₁₇ may arise from the same portion of the MCA. Accordingly, a detailed knowledge of the anatomical features of these important vessels is necessary, in order to avoid injury to them during operative exposure of aneurysms. Although perforating arteries are mentioned very often in the literature, only a few authors have reported data about them.⁶,₁₂,₁₆,₁₇,₂₅,₂₆ For these reasons we decided to examine the perforating vessels in detail, especially their extracerebral segments, lying in the medial part of the Sylvian cistern and extending from the MCA main trunk to the anterior perforated substance.

Clinical Material and Methods

The perforating arteries of 50 human forebrain hemispheres were examined after being fixed in formalin solution for 3 weeks. In all cases, the rostral third or half of the temporal lobe was removed as far as the anterior perforated substance so as to expose the perforating arteries. These small vessels were microdissected under magnification. Arachnoid, as well as superficial and deep middle cerebral veins, were carefully removed. The 36 best prepared hemispheres were selected and used for examination of the relationship between the number and size of perforating arteries. The data were analyzed using Fisher's test of exact probability. Other features of perforating vessels were examined in an additional 240 unfixed forebrain hemispheres.

Results

In examining the perforating arteries special attention was paid to their number, size, origin, shape, and direction, and to the presence of anastomoses.

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The average number of perforating arteries arising from the MCA was nine, with a range of three to 18 (Fig. 1). Relating the number to the size of the perforating arteries produced the following results. In 19 specimens there were many small vessels; 11 specimens had only a few arteries, but these were of a large diameter; in three hemispheres, a few vessels existed that were of small caliber; and in three specimens there were many large vessels. With the application of Fisher's test of exact probability, the data indicated a statistical significance of p < 0.001 and a correlation was found between the number and relative size of perforating arteries. In other words, the greater the number of perforating vessels, the smaller was the diameter, and vice versa.

In the same manner, the relationship between the size of perforating branches of the MCA and the size of Heubner's artery arising from the anterior cerebral artery was examined. A positive relationship was noted in nine of the 36 specimens studied, but this was not of statistical significance (p > 0.025) by Fisher's test. Thus, in a majority of cases there is no correlation between development of perforating arteries and the size of Heubner's artery.

Anatomical Description

Based on their morphological and topographical features, the perforating arteries were divided into medial, middle, and lateral groups (Fig. 2 left). The characteristics of these vessels are presented for each group separately.

Medial Perforating Arteries. The medial arteries arose from the MCA just distal to the carotid bifurcation and the site of the anterior choroidal artery (Fig. 2). These vessels were present in 86% of the specimens. They ranged in number from one to five, but most often two arteries were present (Fig. 2 right). The diameter of the vessels varied: in 65.1% of the cases they were very thin, in 18.6% medium-sized, and in 16.3% large. In almost all cases the medial vessels branched directly off the MCA trunk. In four cases they arose from cortical branches of the MCA (usually from the temporopolar artery). The medial branches most commonly originated as single vessels, but in one-sixth of the hemispheres they branched from common stems.
FIG. 3. Diagram showing the site of origin of perforating arteries. These arteries arose from the proximal segment of the middle cerebral artery (MCA), either as individual vessels (a) or sharing a common stem (b); from collateral (cortical) branches (CB), either from their site of origin (c), or sharing a common stem (d), or from the proximal portion of cortical branches (e); from the bifurcation of the MCA (f); or from the terminal branches (TB) (g). ICA = internal carotid artery; ACA = anterior cerebral artery.

Medial perforating arteries usually coursed dorsally, caudally, and slightly laterally. Sometimes, however, they ran medially at first, forming curves or even loops above the carotid bifurcation, and only then took their final direction.

Middle Perforating Arteries. This group of vessels originated from the middle third of the proximal segment (M₃) of the MCA (Fig. 2). They were found in 88% of the specimens. The average number of these vessels was three, with a range of one to seven. They were small in diameter in 50% of the hemispheres, medium-sized in 16%, and large in 34%. The majority of these vessels arose from the MCA's main trunk (Fig. 2). In one-fourth of the specimens one or more vessels originated from the following cortical branches: the lateral orbitofrontal artery, the temporopolar artery, the anterior temporal artery, and the middle temporal artery. One perforating vessel was noted to arise from the bifurcation of the MCA trunk (in a specimen in which the MCA divided early).

Common stems of the middle perforating branches were observed in more than one-third of the specimens. One or two such stems were often present in the same specimen and these always arose from the MCA trunk. In three cases, in addition to individual perforating branches, common stems gave off small pial vessels. In one of these, the vessel was short, extending to the olfactory trigone and the lateral olfactory stria, and was considered an olfactory ramus. In the other two, the common stems were longer; they extended laterally, reaching the limen insula and the first short insular gyrus, and thus were identified as insular rami. Finally, when there were no medial perforating branches as such, these vessels actually arose from common stems of the middle vessels as collateral branches.

The middle perforating arteries most commonly had a medial, then dorsal and slightly caudal or rostral course, but sometimes they ran ventrally before taking these directions.

Lateral Perforating Arteries. The vessels in the lateral group originated at the level of the terminal third of the M₃ segment (Fig. 2 left), or at the level of the genu of the MCA. This group was more constant. The arteries were well developed and large in diameter in 80% of the specimens. The most lateral vessels were often less developed than the others in this group. The arteries varied in number from one to nine; most frequently four arteries were present.

In all specimens one or more lateral perforating arteries arose from the MCA main trunk (Fig. 2 left),
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but many of them originated in another manner, from
cortical branches or from the division or a terminal
branch of the MCA (Fig. 3). They arose most often (in
almost two-thirds of cases) from collateral (cortical)
branches of the MCA (Figs. 1 and 3). The following
relationship between these vessels was observed: 1) per-
forating arteries most commonly arose from the proxi-
mal portions of the collateral branches (Figs. 1 and 3e);
2) less frequently, they originated at the site where a
Corresponding cortical branch arose (Fig. 3c); and 3) in
a few cases, large perforating vessels shared common
stems with certain cortical branches (Figs. 3d and 4).

While one cortical branch may give rise to one to
two lateral perforating arteries, one, two, or three cor-
tical branches of the same MCA may give off similar
perforating vessels. Almost as a rule, collateral branches
were situated ventrally, that is, from 2 to 13 mm distal
to the MCA trunk (Fig. 1). Thus, the perforating vessels,
arising from collateral branches, occasionally had twice
as long a course as those originating from the MCA
trunk. Such vessels always ran across the anterior or
posterior surface of the MCA trunk to reach the anterior
perforated substance (Figs. 1 and 3c, d, and e). Cortical
branches, giving off perforating arteries, supplied vari-
ous parts of the frontal and temporal lobes and con-
stituted the lateral orbitofrontal, prefrontal, anterior
temporal, and middle temporal arteries. Lateral perfor-
ating vessels arose either from individual cortical arter-
ies or, more frequently, from common stems of cortical
arteries.

In one-sixth of the specimens, perforating branches
originated at the bifurcation of the MCA (Fig. 3f) or in
close proximity to it. In one-third of the cases, they
originated from stems arising from the MCA trunk (Fig.
3g). One to five branches arose from dorsal or ventral
stems, or from both. In a case of trifurcation of the
MCA trunk, one perforating vessel branched off the
middle terminal stem.

Common stems of the lateral perforating arteries
were observed in half of the specimens (Figs. 3b and 5).
One or two such stems were often present in the same
specimen. In some cases, almost all the perforating
arteries arose from common stems (Fig. 5). Some of the
stems gave rise to individual vessels a few millimeters
away from the MCA trunk (Fig. 6), but others branched
only when they reached the anterior perforated sub-
stance (Fig. 5b). Common stems sometimes gave rise
to middle perforating branches.

The lateral perforating arteries most often arose from
the dorsal surface of the MCA trunk, but occasionally
from its rostral, caudal, or even ventral surface. From
their origin, they turned medially (Fig. 2 left), running
beside the M1 segment, and joined the middle group of
vessels. Thus, all the perforating arteries tended to
converge distal to the medial half of the M1 segment
(Fig. 7). The lateral perforating vessels curved sharply
dorsally, laterally, and slightly rostrally or caudally,
forming tight curves or loops before piercing the ante-
rior perforated substance; these arteries almost always
had the shape of an S.

Incidence of Anastomosis

In the 240 hemispheres examined for anastomoses,
no typical anastomotic vessels were found among the
perforating arteries. In two cases fusion between a large
perforating artery and the main trunk of the MCA was
observed (Fig. 8). This vessel was approximately 1.5
mm in diameter.

Discussion

Perforating branches of the middle cerebral artery
(MCA) can be important in many cerebrovascular dis-

![Fig. 6. Specimen with a very short common stem (arrowhead) giving rise to three lateral perforating branches (white arrows). Note the origin of a perforating artery (black arrow) from the common stem (cs) of cortical branches close to the genu (g) of the left middle cerebral artery (MCA).](image)

![Fig. 7. Specimen showing the convergence of perforating arteries (pa) at the level of the anterior perforated substance (between the two arrowheads). MCA = proximal segment of right middle cerebral artery (displaced slightly rostrally); ICA = internal carotid artery.](image)
eases. Some of the diseases affect the vessels themselves and cause ganglionic and capsular infarctions or hemorrhages. 6, 25 The others, however, affect the parent vessel (namely, the proximal (M0) segment of the MCA), and compromise the blood flow through the perforating vessels. This last group of diseases includes atheromas, thrombosis, embolization, aneurysms, subintimal hemorrhage, dissection, and vasculitis of the MCA trunk. 2 From a neurosurgical point of view, obstruction and aneurysms of the MCA are of the greatest interest.

In these specimens there were no anastomotic channels among the perforating branches, nor between them and the other vessels. Accordingly, if the MCA is occluded between the site of origin of the perforating branches and the bifurcation of the internal carotid artery, ischemia will develop in the basal ganglia and internal capsule. The only way to provide sufficient blood supply to these regions is by endarterectomy or extracranial-intracranial bypass procedures. 5, 8, 10, 16 However, great care must be taken while making incisions or while placing temporary clips on the MCA, because the perforating arteries can be situated all around the MCA trunk. Many perforating vessels arise from cortical branches and then run across the rostral or caudal surface of the MCA trunk. Some of the vessels originate from rostral, caudal, or even ventral parts of the trunk. Other vessels, arising from a dorsal part of the MCA, at first traverse the rostral or caudal surface of the artery, and then take a dorsal direction and ascend toward the anterior perforated substance.

Aneurysms are often located in close proximity to the perforating arteries, 1, 2, 9, 15, 20, 24 Aneurysms may influence the perforating branches in various ways. They can compress these vessels and sometimes are sources of microemboli. 22 Subarachnoid hemorrhage following aneurysm rupture can cause spasm of these vessels, 43 and these perforating branches can be injured during an operation on such aneurysms. 16, 21, 23

The nature and extent of aneurysmal damage depends mainly on the anatomical characteristics of the perforating vessels and on the location and size of aneurysms. The medial perforating branches may be damaged not only by aneurysms of the MCA, but also by those of the internal carotid artery that are located at its bifurcation or close to the site of the anterior choroidal artery. 20 On the other hand, the middle and especially the lateral perforating vessels are in close proximity to aneurysms of the MCA that are located at the initial portion or at the bifurcation of the MCA. 1, 9, 15, 19, 20, 24

Aneurysms of the initial part of the MCA may originate at the main trunk or at the branching site of a cortical vessel. 1 As has been observed in this study, perforating arteries often arise from cortical branches. Consequently, aneurysms located at the branching site may impinge on both vessels and may cause both cortical and ganglionic infarctions. 1

Aneurysms are more often situated at a division site of the MCA trunk. As already mentioned, lateral perforating vessels may originate from the terminal portion, the bifurcation, and terminal branches of the MCA trunk. Accordingly, the neck of an aneurysm is often in close proximity to the origin of the lateral perforating vessels. The aneurysm fundus may be also surrounded by perforating arteries. Some of them may even be attached to the aneurysmal sac. 24 Great care should be taken during ligation, clipping, or wrapping of aneurysms in order to avoid injury to the perforating arteries.

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