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Arterial vascularization of primary motor cortex (precentral gyrus)

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Abstract

Background: The precentral gyrus (PG) is the primary motor area and is one of the most eloquent brain regions of neurosurgical interest. Although the arterial supply to the PG is generally known, contributions from different arterial branches such as the anterior cerebral artery (ACA), posterior cerebral artery (PCA), and middle cerebral artery (MCA) have not been comprehensively studied. The aim of the present study was to provide detailed information about the arteries of the PG.

Methods: Twenty adult human brains (40 hemispheres) were obtained, and ACA, MCA, and PCA were separately cannulated and injected with latex. The PG was identified.

Results: The ACA supplied the medial one third and the MCA supplied the lateral two thirds of the PG. The PCA did not reach the PG in any of the hemispheres. In 16 hemispheres (40%), the callosomarginal artery and, in 13 hemispheres (32.5%), the pericallosal artery were dominant for the medial one third of the PG. In 11 hemispheres (27.5%), equal dominance was observed. MCA branches at the lateral tip of the PG were classified into precentral, central, and postcentral groups. In 29 hemispheres (72.5%), the central group and, in 4 hemispheres (10%), the precentral group were dominant for the lateral two thirds of the PG. In 7 hemispheres (17.5%), the precentral and central groups were equally dominant. No dominance was identified for the postcentral group.

Conclusion: In each hemisphere, the PG was supplied by different vascularization patterns of ACA and MCA. The present study is the first to describe and discuss these details. Therefore, awareness of this pattern will provide a great contribution to surgical interventions.

Keywords: Primary motor cortex; Precentral gyrus; Vascular anatomy; Cadaveric study

1. Introduction

The PG is a functionally unique region in the central nervous system. The PG is the primary motor cortex, which is traditionally considered the cortical area for voluntary movement. As shown with electrical stimulation of the cortical surface, the muscles of the body are represented systematically but disproportionately along the gyrus. Classically, this topographic organization is labeled as "motor homunculus" [11]. The blood supply of the medial part of the motor strip is from branches of the ACA, whereas the blood supply of the lateral part of the motor strip is from the central sulcus arteries (rolandic arteries), which are branches of the MCA [4-6,11,13,18,20,22,23]. However, arterial organization of the PG has not yet been studied comprehensively. This study was aimed to provide detailed information about the blood supply PG area.

2. Materials and methods

Forty cerebral hemispheres from 20 adult cadaveric brains were obtained. Brains having signs of central nervous system trauma or disease were excluded. The ACA, MCA,

Abbreviations: PG, precentral gyrus; ACA, anterior cerebral artery; PCA, posterior cerebral artery; MCA, middle cerebral artery.

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and PCA were separately cannulated and injected with colored latex. The PG was identified. The ACA, MCA, and PCA were followed from their origin to the termination of each cortical branch with particular attention to the PG.

3. Results

The PG was striplike in all hemispheres and interdigitated with the middle frontal gyrus in 10 (25%) or with the superior frontal gyrus in 6 (15%) hemispheres. No obvious interdigitation was seen in 24 hemispheres (60%) (Fig. 1). The ACA supplied the medial one third and the MCA supplied the lateral two thirds of the PG. The callosomarginal artery was dominant in 16 hemispheres (40%) and the pericallosal artery was dominant in 13 hemispheres (32.5%) in supplying the medial one third of the PG. In 11 hemispheres (27.5%), equal dominance was observed. Although the callosomarginal arterial branches reached the PG in all the hemispheres, the pericallosal arteries did not supply the PG in 5 hemispheres (12.5%). The pericallosal arteries, on the other hand, anastomosed with the callosomarginal arteries and then reached the PG in 2 hemispheres (5%). In 1 brain (5%), there was 1 ACA distal to the anterior communicating artery (azygos).

In 6 hemispheres (15%), there were variations either in the course or in the origin of the callosomarginal artery. In these hemispheres, the callosomarginal artery or its branches approached the frontal pole as close as 1.8 to 2 cm and then followed a highly tortuous course to reach the PG. Interestingly, in one of these hemispheres (2.5%), the callosomarginal and frontopolar arteries originated from the ACA as a common trunk and then reached the PG (Fig. 2). In one specimen in which the ACA on both sides bifurcated into the callosomarginal and pericallosal arteries, the pericallosal artery on one side crossed over the corpus callosum and supplied the medial side of the contralateral hemisphere (Fig. 3).

The MCA branches at the lateral tip of the PG were classified as precentral, central, and postcentral groups

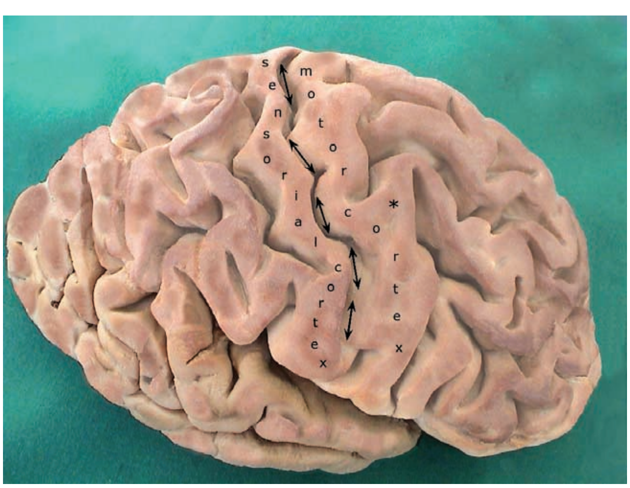

Fig. 1. Photograph of the right cerebral hemisphere after pia-arachnoid and cortical vessels have been removed. The striplike motor cortex is indicated with arrows. The motor cortex is connected with the middle frontal gyrus in the area marked with an asterisk.

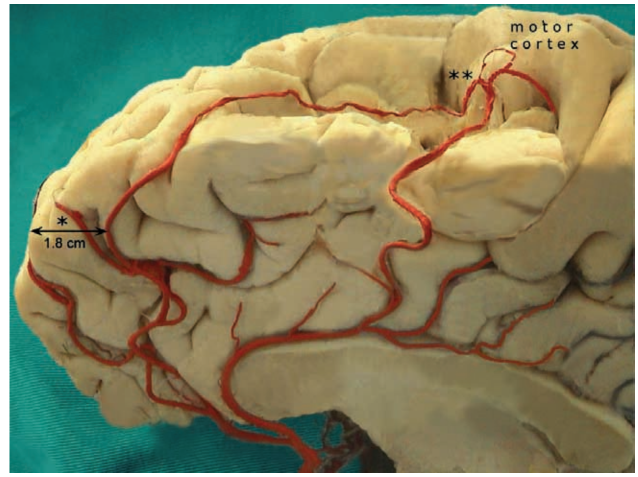

Fig. 2. Photograph of the right cerebral hemisphere. A common trunk originating from the ACA immediately after the anterior communicating artery (single arrow) gives rise to the callosomarginal and frontopolar arteries. The callosomarginal artery (single asterisk) in this specimen has a very tortuous course and comes as close as 1.8 cm to the frontal pole. It then reaches the motor cortex (two asterisks) and anastomoses with a branch of the distal pericallosal artery (double arrow).

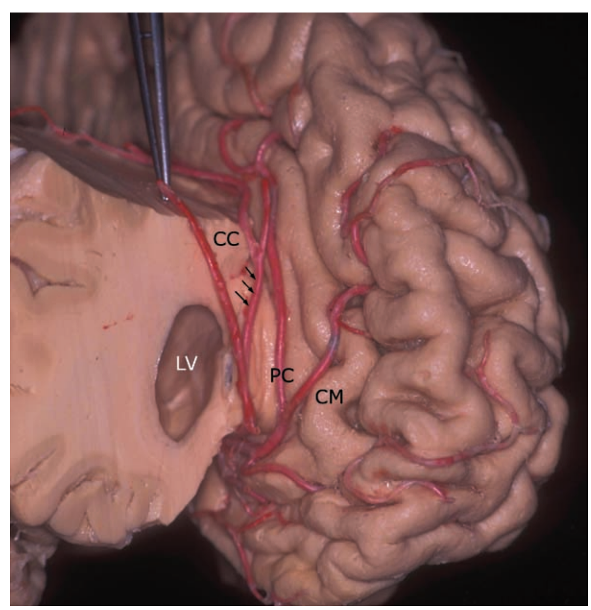

Fig. 3. Photograph of the left cerebral hemisphere. The right hemisphere has been partially removed in a coronal plane to expose the corpus callosum and the frontal horn of the right lateral ventricle. The left ACA bifurcates into the callosomarginal and pericallosal arteries at the level of the genu of the corpus callosum. The surgical instrument is pulling the right callosomarginal artery to better show the bifurcation of the right ACA. The right pericallosal artery (arrows) crosses over the corpus callosum to supply the contralateral medial hemisphere as a variation seen in this cadaveric specimen. CC indicates corpus callosum; LV, lateral ventricle; PC, pericallosal; CM, callosomarginal.

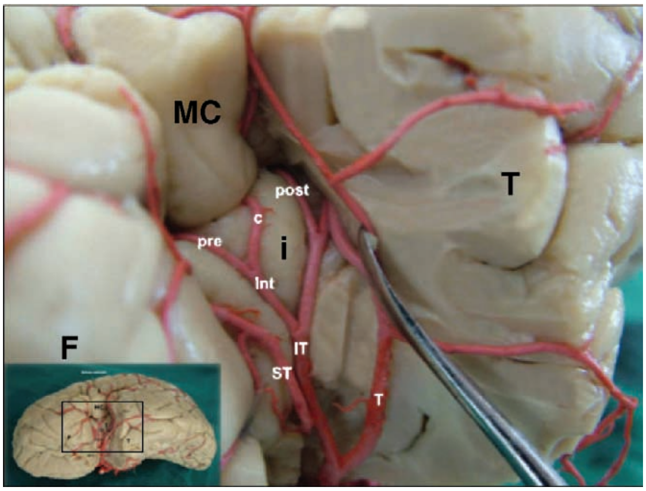

Fig. 4. The relation of precentral, central, and postcentral arteries with the bifurcation of the MCA into its trunks and the region they supplied in the left cerebral hemisphere. The temporal operculum has been removed to show the insula, motor cortex, and branches of the MCA. The central group of arteries has been found to be dominant in this hemisphere. MC indicates motor cortex; post, postcentral artery; T (black), temporal lobe; c, central artery; pre, precentral artery; i, insula; int, intermediate trunk; F, frontal lobe; IT, inferior trunk; ST, superior trunk; T (white), early temporal branch.

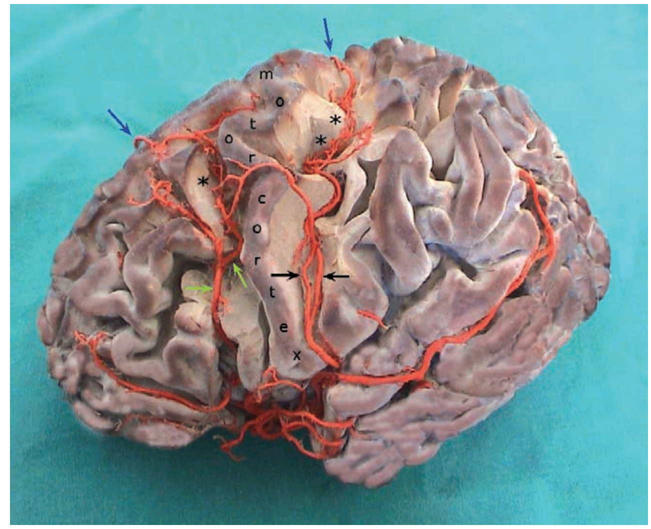

Fig. 6. The anastomoses between ACA and MCA branches in the motor cortex are seen. The blue arrows indicate the branches arising from ACA, the green arrows point to the branches off precentral arteries, and the black arrows point to the branches off the central arteries. The areas of anastomoses between ACA and precentral artery (single asterisk) and between ACA and central artery (two asterisks) are shown. To better demonstrate the areas of anastomoses, some tissue on and around the motor cortex has been removed.

(Figs. 4 and 5). In 29 hemispheres (72.5%), the central group, and in 4 hemispheres (10%), the precentral group were dominant for the lateral two thirds of the PG. In 7 (17.5%) hemispheres, the precentral and central groups were equally dominant. No dominance was identified for the postcentral group. The PGs of all the hemispheres were supplied by precentral and central groups. In 13 hemispheres (32.5%), the postcentral group did not give any branches to the PG. The branches running to the PG from the postcentral group were thin cortical branches passing via the postcentral gyrus. In 8 hemispheres (20%), there were thin branches running proximal to arteries of the postcentral group and to the most lateral part of the PG. In 3 hemispheres (7.5%), however, there were anastomoses at the lateral tip of the PG closest to the sylvian fissure between

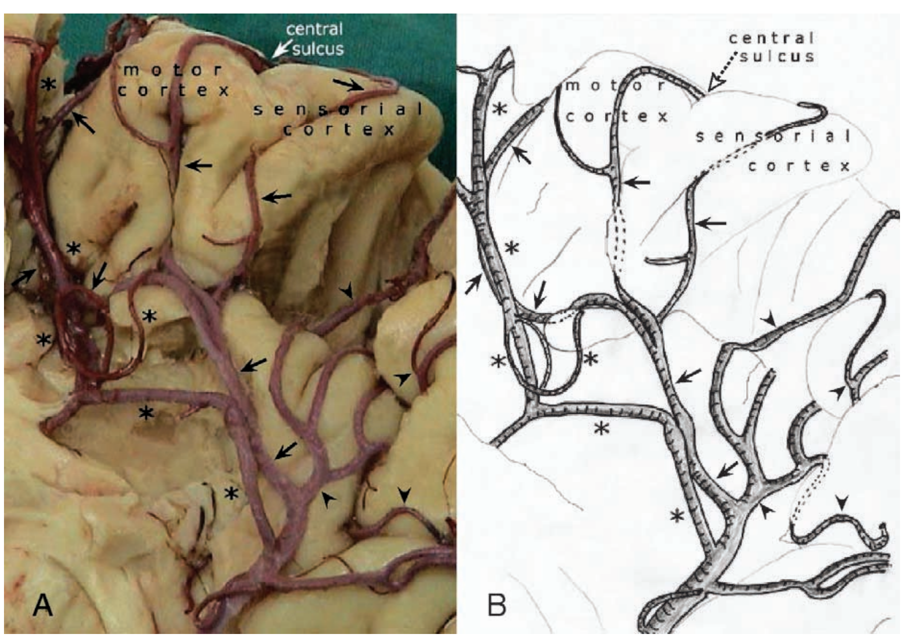

Fig. 5. In the picture (A) and illustration (B), the precentral, central, and postcentral arteries are shown to supply the PG. The precentral arteries (marked with an asterisk) reach the frontal PG and branch off. The central artery (marked with creased arrow) surrounds the PG with its 2 branches, one coursing in the front and the other in the back (the branch coursing to the central gyrus also gives one more branch over the motor cortex) supplying the area. The postcentral artery (marked with plain arrow) does not give any branches to the motor cortex in this area.

the postcentral and central group arteries. Although central group arteries coursed as 2 or 3 vessels in the central sulcus and at the base of the PG, precentral group arteries usually coursed as 1 or 2 arteries in the precentral sulcus. Also, precentral group arteries passing to the middle frontal gyrus turned posteriorly and provided thin cortical branches to the PG. All the arteries running from the MCA to the PG turned into very thin branches in the lateral two thirds of the motor strip and some anastomosed with the terminal branches originating from the ACAs (Fig. 6). At this junction, there was less robust arterial vascularization. The PCA did not reach the PG and did not anastomose with arteries reaching the PG in any of the hemispheres.

4. Discussion

The PG is 10 to 12 cm long and 10 to 12 mm wide, and its cortical mantle is 3.5 to 4.5 mm thick [11,12]. Cortical mapping studies have demonstrated that there is a topographic representation of movements along the PG. The PG is electrophysiologically well defined [9-11]. However, the arterial supply of the PG has not been comprehensively defined.

The A2 segment of the ACA terminates near the junction of the rostrum and genu of the corpus callosum. At this point, the distal ACA often appears to bifurcate into 2 main vessels. The pericallosal artery represents the continuation of the main ACA trunk, and it courses at a variable distance above the corpus callosum. The other vessel is the callosomarginal artery, which passes over the cingulate gyrus and runs posteriorly within the cingulate sulcus [4,13,15,16,21,25]. Its most frequent origin is from the A3 segment [16,18]. A discrete callosomarginal artery is present in approximately 50% of cerebral angiograms [13]. In 85% of the hemispheres investigated in this study, there were callosomarginal arteries. In 1 hemisphere (2.5%), callosomarginal and frontopolar arteries had a common trunk originating from the very early A2 segment of the ACA. This is in accordance with previous angiographic findings (9%) reported by Krayenbuhl and Yasargil [10].

More emphasis was placed on the course of the callosomarginal artery because it was the most significant factor in the vascularization of the medial one third of the PG. When the callosomarginal artery branched off the distal part of the anterior communicating artery, the PG in these hemispheres was mainly supplied by branches of the pericallosal artery. Furthermore, the callosomarginal arteries in these hemispheres (15%) had a very tortuous course. In its course, the callosomarginal artery ran as close as 1.8 to 2 cm to the frontal pole, then turned posteriorly and gave thin perforators into the PG. This may represent valuable information in surgical interventions involving the frontal lobe. The coagulation of these arteries in frontal lobe surgery (frontal lobectomies, falx meningiomas, frontal glial tumors, distal ACA aneurysms, and others) may lead to motor deficits in these patients [1,2,7,8,14,17]. This is also relevant for surgery involving the superior frontal gyrus, where the supplementary motor area is located. Contralateral transient weakness that may occur after the supplementary motor area manipulation is initially indistinguishable from damage to the primary motor cortex. However, recovery is different, and supplementary motor area deficits may resolve completely within days or weeks [10,14,19]. Peraud et al [14] presented the surgical results of 24 grade II astrocytomas located in the superior frontal gyrus. They reported postoperative motor deficits in 21 of 24 patients, 11 of whom recovered quickly. Seven patients whose tumors extended to the precentral sulcus still had motor deficits at 1-year follow-up. They concluded that surgery for grade II gliomas in the superior frontal gyrus is more likely to result in permanent morbidity when the resection is performed at a distance of less than 0.5 cm from the PG. This is true and commonly agreed upon. However, the vascular trauma, especially when involving the callosomarginal artery or its branches, as was emphasized in our cadaver study, may occur further from the PG and still lead to permanent deficits.

The size of the pericallosal artery distal to the origin of the callosomarginal artery is inversely related to the size of the callosomarginal artery. Early angiographic studies by Krayenbuhl and Yasargil [10] demonstrated that the size of the callosomarginal artery was larger than that of the pericallosal artery in 44% of cases, was equal in 34%, and was smaller than the pericallosal in 23%. Results of the present study confirm these findings. In 40% of the hemispheres studies, the callosomarginal artery was found to be the dominant arterial supply to the medial one third of the PG.

On the lateral surface of the brain, the precentral sulcal branch of the MCA appears on the posterior part of the frontal lobe or the anterior edge of the parietal operculum. It courses superiorly, giving off 1 or 2 main branches between the precentral and central sulci. The central sulcal artery consists of 1 or 2 main branches that extend onto the convexity and course posterosuperiorly between the precentral and postcentral sulci toward the superior margin of the hemisphere. The postcentral sulcal artery initially follows the postcentral sulcus and then courses in the intraparietal sulcus. As previously stated in various studies, the branches of MCA and their courses may vary [3,5,13,23,24]. Furthermore, when all the attention is directed at a single gyrus only, the vascularization pattern may become even more complicated. Therefore, the vessels coursing toward the precentral sulcus or regions anterior to the precentral sulcus were named precentral group; those coursing toward the PG and central sulcus were named central group, and those coursing to the postcentral gyrus and sulcus were named postcentral group. Previous studies have defined the distribution of insular (M2) segments. Accordingly, the MCA may divide into intermediate (central) trunk as well as superior and inferior trunks in M2 [13,22,24]. In our study, the intermediate trunk was detected in 30 hemispheres (75%). The intermediate trunk originated from the superior trunk in 25 hemispheres (62.5%) and from the inferior trunk in 5 hemispheres (12.5%). In all the hemispheres with an intermediate trunk, the precentral and central group of arteries stemmed from this trunk (Fig. 4). Although the precentral and central groups of arteries originated from the superior trunk in all of 10 hemispheres with no intermediate trunk (25%), the postcentral artery originated from the superior trunk in 3 hemispheres and from the inferior trunk in 7 hemispheres. In this study, the PG was mostly supplied by the central group. There were thin branches running to the furthermost inferior part of the PG from arteries in all 3 groups. This area was the most vascularized area of the motor cortex. Some vessels running anterior to the precentral sulcus were then turning posteriorly and giving thin branches to the central one third of the PG. The vascularization pattern encountered in each hemisphere was definitely different, to varying degrees, and this should particularly be kept in mind.

5. Conclusion

The PG, the primary motor cortex, is a highly eloquent area. The literature presents no detailed study on its vascularization. The present study is the first to describe and discuss these details.

The callosomarginal branches of the ACA were slightly more dominant than the pericallosal branches in supplying the medial one third of the PG. The central sulcus group of arteries originating from the superior or the intermediate trunk of the MCA was significantly more dominant than the precentral and postcentral groups in supplying the lateral two thirds of the PG. In each hemisphere, the PG was supplied by different vascularization patterns of ACA and MCA. Variability, as elsewhere in the brain angioarchitecture, remains the norm here as well.

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