



# The segmentation of the posterior cerebral artery: a microsurgical anatomic study

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## Abstract

There are still different descriptions of the segmentation of the posterior cerebral artery, although there is a radiological and anatomical consensus on the segmentation of the anterior and the middle cerebral artery. This study aims to define the most appropriate localization for origin and end points of the segments through reviewing the segmentation of the posterior cerebral artery. The segments and the cortical branches originating from those segments of the 40 posterior cerebral arteries of 20 cadaver brains were examined under operating microscope. In this research, the P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>, P<sub>4</sub>, and P<sub>5</sub> classification of the segmentation of the posterior cerebral artery is redefined. This redefinition was made to overcome the complexities of previous definitions. The P<sub>1</sub> segment in this research takes its origin from the basilar tip and ends at the junction with the posterior communicating artery. The average diameter of this segment at the origin was 2.21 mm (0.9–3.3), and the average length was 6.8 mm (3–12). The P<sub>2</sub> segment extends from the junction with the posterior communicating artery to the origin of the lateral temporal trunk. This point usually situates on one level of posterior of the cerebral peduncle. The average diameter of this segment at the origin was 2.32 mm (1.3–3.1), and the average length was 20.1 mm (11–26). The P<sub>3</sub> segment extends from the origin of the lateral temporal trunk to the colliculus where both the posterior cerebral arteries are the nearest to each other (quadrigeminal point) and is located at the anterior-inferior of the splenium. The average diameter of this segment at the origin was 1.85 mm (1.2–2.7), and the average length was 16.39 mm (9–28). The P<sub>4</sub> begins at the quadrigeminal point and ends at the top of the cuneus. The average diameter of this segment at the origin was 1.55 mm (1.1–2.2). While the P<sub>5</sub> segment is named as the terminal branches of the major terminal branches of the posterior cerebral artery, no definite border was found between the P<sub>4</sub> and the P<sub>5</sub> segments. In this study, the segmentation of the posterior cerebral artery, developed by Krayenbühl and Yaşargil, was redefined to be more appropriate for radiological and anatomical purposes.

**Keywords** Posterior cerebral artery · Microsurgical anatomy

## Introduction

Recently, some detailed anatomical studies on the posterior cerebral artery (PCA) and its branches were carried out by authors [1, 2, 4–6, 9–11, 13, 15, 17–20]. The information from those studies affected the success of surgical approaches to the medial temporal region. As a result, it fostered an

understanding of operations in treating tumours and vascular lesions, especially in selective amygdalohippocampotomy [17, 18]. In spite of such detailed information, there is no consensus on the segmentation of the posterior cerebral artery which is entirely compatible with anatomical and radiological findings [4, 7, 11, 14, 17, 18]. Krayenbühl and Yaşargil classified the PCA in five segments (P<sub>1</sub>–P<sub>5</sub>) according to the angiographical studies [4, 17, 18]. Zeal and Rhoton [19] divided the PCA with some differences into three segments (P<sub>1</sub>–P<sub>3</sub>). Similarly, Seoane et al. also divided the PCA into three segments, S<sub>1</sub>–S<sub>3</sub> [14]. Newton defined the P<sub>1</sub> segment as the peduncular segment, the P<sub>2</sub> segment as the ambient segment, and the P<sub>3</sub> segment as the quadrigeminal segment [3, 7].

The objective of this study is to review the segmentation of the PCA and its cortical branches in order to redefine the segmentation as anatomically and radiologically well-defined.

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## Materials and methods

Microsurgical anatomy of 40 PCAs from 20 cadavers' brains was examined. The internal carotid artery and the vertebral artery were dissected at the neck and then cannulated. After irrigation with distilled water, both arteries were perfused with red coloured (by India ink) latex.

The calvarium and dura were opened to allow the craniums and brains to be fixed for at least 2 months in 10% formaldehyde. Finally, the brains were removed from the craniums.

The course of the PCA, relationship with some neuroanatomical structures, average diameter at various points, and major branches were studied by using an operating microscope of  $\times 6$ – $\times 25$  magnification. Meanwhile, most appropriate points for segmentation were identified. The data were recorded and analysed.

The cadavers in our Institution belong to unclaimed bodies which are delivered from the Forensic Medicine Department according to the rules of legislation. Conducting scientific studies on those bodies or body parts do not require Ethical approval in our University. Since the bodies do not belong to donors and are unclaimed, it is also impossible to take statement of informed consent from their relatives. The basic demographic information about the cadavers are presented in Table 1.

## Results

The terminal bifurcation of the basilar artery within the interpeduncular cistern bifurcates distal to the origin of the superior cerebellar artery inferior to the much larger paired posterior cerebral arteries. Forming the posterior margin of the circle of Willis, the PCA curves superior to the antero-medial portion of the peduncle and joins the posterior communicating artery. Then, it arches postero-laterally around the cerebral peduncle and enters into the ambient cistern. During this course, the artery is in parallel with the course of the basal vein lying superior and the trochlear nerve, tentorial edge, and superior cerebellar artery which all lie inferiorly. The PCA then enters the quadrigeminal cistern. It is branched into its major terminal branches before reaching to the top of the cuneus or in the calcarine fissure.

The PCA was divided into five segments, P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>, P<sub>4</sub>, and P<sub>5</sub>, by Krayenbühl and Yaşargil [4]. That terminology was also used in this study, even though origin and end points of the segments were redefined. It was found that the PCA had mainly two different courses (Figs. 1, 2, 3, and 4a–c).

### The P<sub>1</sub> segment

This segment is named for the portion of the PCA, which is between its origin at the basilar tip and the junction with the posterior communicating artery. The average diameter of this

**Table 1** Demographic information of the cadavers ( $n = 20$ )

Age	Gender	Ethnicity
64	Male	Turkish
57	Male	Turkish
69	Male	Turkish
58	Male	Turkish
52	Female	Turkish
54	Female	Turkish
52	Male	Turkish
50	Male	Turkish
50	Male	Turkish
54	Male	Turkish
53	Male	Turkish
65	Male	Turkish
53	Female	Turkish
80	Male	Turkish
62	Male	Turkish
66	Male	Turkish
54	Male	Turkish
69	Male	Turkish
73	Male	Turkish
70	Male	Turkish

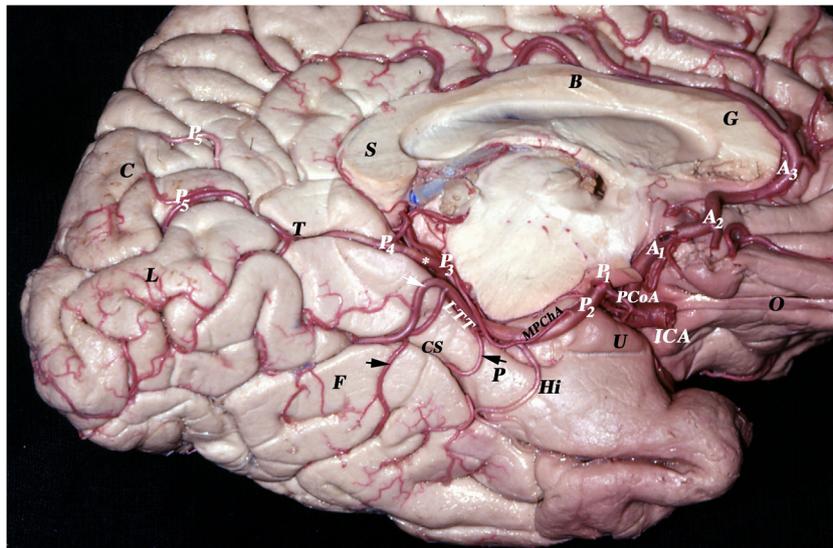
segment at the origin was 2.12 mm (0.9–3.3), and the average length was 6.8 mm (3–12) (Table 2). From this segment, the thalamo-perforating, collicular, and short circumflex branches originate (Figs. 1, 2, 3, and 4a–c).

### The P<sub>2</sub> segment

The P<sub>2</sub> segment extends from the junction with the posterior communicating artery to the origin of the lateral temporal trunk (Figs. 1 and 3). The average diameter of P<sub>2</sub> segment at the origin was 2.32 mm (1.3–3.1 mm), and the average length was 20.1 mm (11–26 mm) (Table 2). The lateral temporal trunk, the medial posterior choroidal artery, the hippocampal artery, and the anterior temporal artery arose also from this segment.

The lateral temporal trunk named as the inferior temporal artery by Yaşargil and originating from the lateral part of the PCA which is also the back part of the cerebral peduncle was found in all hemispheres, curving forward and backward (Figs. 1 and 3). The average diameter of this artery was 1.45 mm (0.9–2.3), and it was the largest branch of the PCA in 35 hemispheres.

The lateral temporal trunk has a typical course, i.e. while it runs anteriorly, it gives temporal branches and then curves to the posterior. The lateral temporal trunk was the sole artery going into the inferior temporal lobe in 11 hemispheres (22.5%). In these hemispheres, the branches of the trunk supplied the anterior and posterior parts of the temporal lobe and the hippocampus.



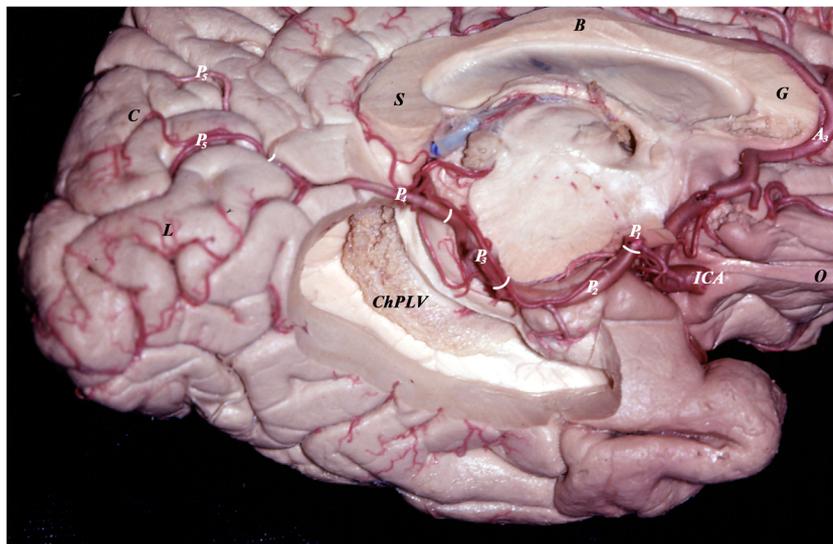
**Fig. 1** Inferior medial view of the left hemisphere.  $P_1$ ,  $P_1$  segment of the posterior cerebral artery;  $P_2$ ,  $P_2$  segment of the posterior cerebral artery;  $P_3$ ,  $P_3$  segment of the posterior cerebral artery;  $P_4$ ,  $P_4$  segment of the posterior cerebral artery;  $P_5$ ,  $P_5$  segment of the posterior cerebral artery;  $A_1$ ,  $A_1$  segment of the anterior cerebral artery;  $A_2$ ,  $A_2$  segment of the anterior cerebral artery;  $PCoA$ , posterior communicating artery;  $MPChA$ , medial posterior choroidal artery arises from  $P_2$  segment of the posterior cerebral artery;  $Hi$ , hippocampal artery

(Uchimura) arises  $P_2$  segment of the posterior cerebral artery;  $LTT$ , lateral temporal trunk;  $G$ , genu of the corpus callosum;  $B$ , body of the corpus callosum;  $S$ , splenium of the corpus callosum;  $O$ , olfactory tract;  $U$ , uncus;  $P$ , parahippocampal gyrus;  $F$ , fusiform gyrus;  $CS$ , collateral sulcus;  $L$ , lingual gyrus;  $T$ , top of the cuneus;  $c$ , cuneus;  $*$ , beginning of the  $P_4$  segment; *black arrows*, origin of the lateral temporal artery; *white arrows*, branches of the lateral temporal artery

There was always a temporal branch before the lateral temporal trunk in 20 hemispheres (Type 1) investigated (50%) (Fig. 4a). If there were two temporal branches, then the first branch was the hippocampal artery (with the average diameter 0.54 mm (0.4–0.7)) and the second was the anterior temporal artery (with the average diameter 0.83 mm (0.2–1.3)).

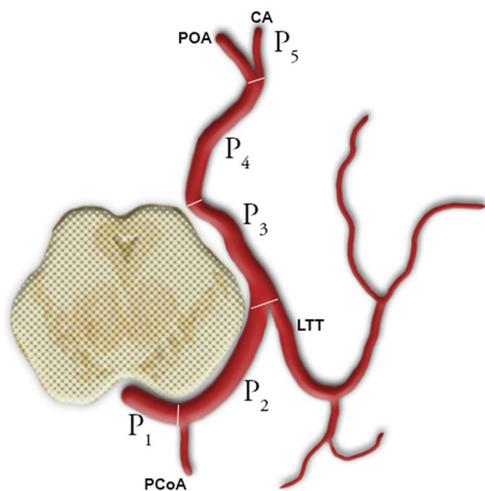
### The $P_3$ segment

The  $P_3$  segment extends from the origin of the lateral temporal trunk to the colliculus where both the posterior cerebral arteries are the nearest to each other (quadrigeminal point) and this quadrigeminal point is located at the anterior-inferior of the



**Fig. 2** Inferior medial view of the left hemisphere. Some part of inferior temporal lobe and lateral temporal trunk was dissected.  $P_1$ ,  $P_1$  segment of the posterior cerebral artery;  $P_2$ ,  $P_2$  segment of the posterior cerebral artery;  $P_3$ ,  $P_3$  segment of the posterior cerebral artery;  $P_4$ ,  $P_4$  segment of the posterior cerebral artery;  $P_5$ ,  $P_5$  segment of the posterior cerebral

artery;  $ICA$ , internal carotid artery;  $A_3$ ,  $A_3$  segment of the anterior cerebral artery;  $LTT$ , lateral temporal trunk;  $G$ , genu of the corpus callosum;  $B$ , body of the corpus callosum;  $S$ , splenium of the corpus callosum;  $O$ , olfactory tract;  $L$ , lingual gyrus;  $C$ , cuneus;  $ChPLV$ , choroid plexus of lateral ventricle

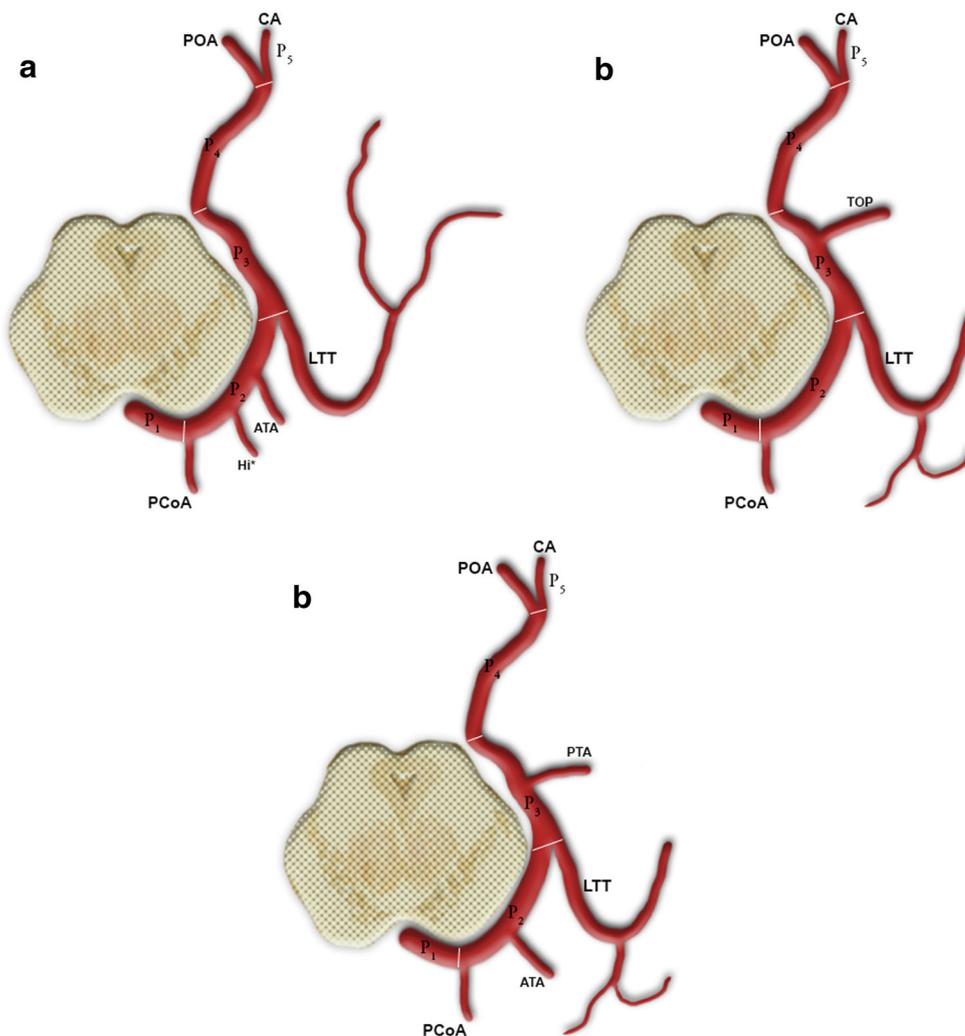


**Fig. 3** The segments of posterior cerebral artery ( $P_{1-5}$ ). White line, borders of the segments of posterior cerebral artery; *PCoA*, posterior communicating artery; *LTT*, lateral temporal trunk; *CA*, calcarine artery; *POA*, parieto-occipital artery

splenium (Figs. 1, 2, and 3). The average diameter of this segment at the origin was 1.85 mm (1.2–2.7), and the average length was 16.39 mm (9–28) (Table 2). The temporo-occipital artery, the lateral posterior choroidal artery, and the thalamogeniculate artery originated from this segment.

The end point of the  $P_3$  segment situated at the antero-inferior of the splenium. Before this point, the artery went in to postero-medial, then curved to lateral. The  $P_3$  segment ran posteriorly and medially and they got nearest to each other behind the colliculus, where it was point quadrigeminal stated by Rhoton [19]. This point is located at anterior-inferior of the splenium and bordered between the  $P_3$  and  $P_4$  segments (Figs. 1, 2, and 3). Three temporal arteries that originated from this segment and ran through inferior part of the temporal lobe (i.e. the middle and the posterior temporal arteries and the temporo-occipital artery) were observed. The anterior temporal artery, lateral temporal artery (middle), and the posterior temporal artery (Type 3) were found only in one hemisphere

**Fig. 4** **a** The type 1 variation of temporal arteries in 20 hemispheres (50%). *PCoA*, posterior communicating artery; *Hi*, hippocampal artery; *ATA*, anterior temporal artery; *LTT*, lateral temporal trunk; *CA*, calcarine artery; *POA*, parieto-occipital artery; \*, there is always a temporal branch before *LTT*. If there are two temporal branches, then the first branch is the hippocampal artery and the second is the anterior temporal artery. **b** The type 2 variation of temporal arteries in 19 hemispheres (47.5%). *PCoA*, posterior communicating artery; *LTT*, lateral temporal trunk; *TOP*, temporo-occipital artery; *CA*, calcarine artery; *POA*, parieto-occipital artery. **c** The type 3 variation of temporal arteries in a hemisphere (2.5%). *PCoA*, posterior communicating artery; *ATA*, anterior temporal artery; *LTT*, lateral temporal trunk (middle); *PTA*, posterior temporal artery; *CA*, calcarine artery; *POA*, parieto-occipital artery



**Table 2** The characteristics of segments of PCA

Segment	Diameter (mm)		Length (mm)	
	Range	Average	Range	Average
P <sub>1</sub>	0.9–3.3	2.21	3–12	6.8
P <sub>2</sub>	1.3–3.1	2.32	11–26	20.1
P <sub>3</sub>	1.2–2.7	1.85	9–28	16.39
P <sub>4</sub>	1.1–2.2	1.55	2.3–19	10.48
P <sub>5</sub>	–	–	–	–

(2.5%) (Fig. 4c), although the temporo-occipital artery (Type 2) was in 19 hemispheres (47.5%) (Fig. 4b). The temporo-occipital artery arose medially in 15 hemispheres (37.5%) and laterally in four hemispheres (10%). When it arose medially, it crossed laterally over the P<sub>3</sub> segment after 1–2 mm from the origin. The temporo-occipital artery originated from lateral part of the P<sub>3</sub> segment between the aqueduct and colliculus in all cases. The average diameter of the temporo-occipital artery was measured as 1.33 mm (0.8–1.9). The lateral temporal trunk was dominant in 21 hemispheres (52.5%) without the temporo-occipital artery and supplied the area where the temporo-occipital artery was supplied.

### The P<sub>4</sub> segment

The P<sub>4</sub> begins behind the colliculus (i.e. the quadrigeminal point) and ends at the top of the cuneus (Figs. 1, 2, and 3). Sometimes it is divided into its major terminal branches (the parieto-occipital and calcarine arteries) before reaching to the top of the cuneus or in the calcarine fissure (Figs. 1, 2, and 3). The average diameter of this segment at the origin was 1.55 mm (1.1–2.2) and the average length was 10.48 mm (2.27–18.93) (Table 2). The parieto-occipital artery originated medially from P<sub>4</sub> segment in 34 hemispheres (85%), while the calcarine artery originated from the lateral part. In the rest, although the arteries arose at the opposite side, they crossed each other 2–3 mm from the origin. Subsequently, the parieto-occipital artery ran medially while the calcarine artery ran laterally.

### The P<sub>5</sub> segment

The terminal branches of the parieto-occipital and the calcarine arteries were defined as the P<sub>5</sub> segment (Figs. 1, 2, and 3).

## Discussion

The PCA firstly appears during the posterior expansion of the forebrain (prosencephalon) or telencephalon. Embryologically, it arises as a branch of the internal

carotid artery and seen as extending posteriorly of the carotid artery [3, 5–7]. As the hemisphere grows backward beyond the midbrain, the thalamus, and the visual centres, the inflow of blood into the PCA is no longer supplied through the internal carotid artery but from the basilar artery [3, 5–7].

The PCA was divided into five segments, P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>, P<sub>4</sub>, and P<sub>5</sub>, by Krayenbühl and Yaşargil [4]. Zeal and Rhoton had made some changes based upon this system [19].

The P<sub>1</sub> was named for the portion of the PCA, which was between its origin at the basilar tip and the junction with the posterior communicating artery. This segment was also identified as peduncular, pars precommunicating, mesencephalic, circular, or basilar segment. There was a consensus among the authors regarding its origin and ending points [2, 3, 7, 8, 12, 17, 18, 21].

The P<sub>2</sub> segment (also called as the pars postcommunicating, the ambient, or the perimesencephalic segment) was the part of the PCA in the ambient [3, 7, 17, 18]. Krayenbühl and Yaşargil (1968) identified the P<sub>2</sub> segment the part from the posterior communicating artery to the inferior temporal artery which was the first cortical branch of the PCA [4]. On the other hand, in this study, the origin of the lateral temporal trunk was designated as the junction of the P<sub>2</sub>–P<sub>3</sub>, according to the findings. The lateral temporal trunk was usually found in the forward and backward directions of the posterior margin cerebral peduncle. Since it was observed in all hemispheres and originated from the lateral part of the PCA, this artery was named as the lateral temporal trunk. The artery had some characteristic features. For these reasons, the origin of the artery could be defined as the border between the P<sub>2</sub> and the P<sub>3</sub> segments. The reasons naming the lateral temporal trunk as “trunk” were as follows: (1) the PCA had a bifurcation-like feature at the posterior margin of the pedunculus, likewise the middle cerebral artery had; (2) this artery was the largest branch of the PCA in 35 hemispheres investigated (87.5%); and (3) it supplied much more area than the other branches of the PCA. In addition, the lateral temporal trunk had a very typical course.

The temporo-occipital artery could be easily distinguished from the lateral temporal trunk, because it arose from the colliculus before the P<sub>3</sub> segment. The origin of the artery from the PCA could be easily seen in angiographical images. Arising from near the posterior margin of the cerebral peduncle in all hemispheres was another typical feature of the lateral temporal trunk. The P<sub>2</sub> segment branches into the medial posterior choroidal, the hippocampal, and the anterior temporal arteries. In 50% ( $n = 20$ ) of the hemispheres investigated, one or two branches (the hippocampal and the anterior temporal arteries), which ran anterior of the temporal lobe, were found before the lateral temporal trunk arose in the P<sub>2</sub> segment. The hippocampal artery arose directly from the P<sub>2</sub> segment in four hemispheres

(10%). Uchimura named this artery as Uchimura artery, while Marinkovic as anterior hippocampal artery [9, 16].

Zeal and Rhoton divided the P<sub>2</sub> segment into P<sub>2A</sub> (anterior) and P<sub>2P</sub> (posterior) [19]. The P<sub>2A</sub> segment begins at the posterior communicating artery and ends around the cerebral peduncle. The P<sub>2</sub> segment begins from this point and ends at the pulvinar. There was some discordance between radiological and anatomical findings in this segmentation leading to difficulties.

Yaşargil identified the P<sub>3</sub> segment as the part from the origin of the inferior temporal artery to the origin of the parieto-occipital and calcarine arteries [17, 18]. According to Zeal and Rhoton, the segment originates from the posterior margin of the cerebral peduncle and ends at the anterior limit of the calcarine fissure [19]. However, our findings show that the origins of those arteries differed in the cases, which could potentially lead to some difficulties in identification of the border between the P<sub>3</sub> and P<sub>4</sub> segments. For this reason, we believe that the P<sub>3</sub> segment begins at the origin of the lateral temporal trunk, runs posteriorly and medially, and ends behind of the colliculus. The artery is closest to the artery of the opposite side at this point (i.e. the quadrigeminal point). This point is located at anterior-inferior of the splenium. This curved point and bordered between the P<sub>3</sub> and P<sub>4</sub> segments could be easily seen in angiographical images. The part between the origin of the lateral temporal trunk and quadrigeminal point was termed as the P<sub>3</sub> segment.

Since the origin of the P<sub>3</sub> segment defined by Rhoton could not be seen in angiographic images, it would be difficult to accept this point as a landmark. Although Yaşargil called the point of the origin of parieto-occipital and calcarine arteries as the end of the P<sub>3</sub> segment, the origins of those arteries have variations [5, 6, 17–19]. For this reason, we believe that applying the point of the origins of those arteries as an end point of the P<sub>3</sub> segment would not be a good landmark, particularly during surgical approaches. Furthermore, the quadrigeminal point as we designated for end of the P<sub>3</sub> segment could easily be seen in angiographic images.

The P<sub>4</sub> segment was identified by Kraysenbühl and Yaşargil and Rhoton as the calcarine and the parieto-occipital arteries [4, 19]. We designated the P<sub>4</sub> segment, which begins behind the colliculus (the quadrigeminal point), curves to posterior and lateral, and ends at the top of the cuneus. The end point of the P<sub>4</sub> segment according to the findings of the study was the end point of the P<sub>3</sub> segment defined by Rhoton [19].

The parieto-occipital and calcarine arteries were sometimes in this segment, sometimes in the P<sub>5</sub> segment.

We named the branch of the PCA named as lateral occipital artery by arising Lang as the temporo-occipital artery for the last temporal branch arising from the aqueduct before the colliculus that was observed in 19 hemispheres [6] (47.5%). Although this artery was the largest temporal artery in five hemispheres (12.5%), in the rest, the lateral temporal trunk

was. The study revealed that branches arising from the lateral temporal trunk supplied the blood to the area in 21 hemispheres when the temporo-occipital artery was not (52.5%).

Kraysenbühl and Yaşargil in angiographical images and Lang in his anatomical dissections have shown that the medial occipital artery gives the parieto-occipital and the calcarine arteries at the colliculus [4–6]. The authors have also pointed out that the lateral occipital artery was the last branch going through the temporal lobe. We named the lateral occipital artery as the temporo-occipital artery. Although Yaşargil and Lang designated that the medial occipital artery was a branch of the PCA, we observed that they were the P<sub>3</sub> and P<sub>4</sub> segments themselves [4–6].

We identified the P<sub>5</sub> segment, likewise other authors [10, 11, 17, 18], as the terminal branches of the parieto-occipital and the calcarine arteries.

As a result, our findings were in line with Kraysenbühl and Yaşargil's [18]. Actually, our findings were a combination of Yaşargil and Rhoton's classifications. However, in this study, the borders of origins and ends of the P<sub>3</sub> and the P<sub>4</sub> segments in our study were defined. The designated borders were also in consistent with the anatomical and radiological images.

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