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ORIGINAL COMMUNICATION

Arterial Vascularization Patterns of the Splenium: An Anatomical Study

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The aim of this study was to provide detailed information about the arterial vascularization of the splenium of the corpus callosum (CC). The splenium is unique in that it is part of the largest commissural tract in the brain and a region in which pathologies are seen frequently. An exact description of the arterial vascularization of this part of the CC remains under debate. Thirty adult human brains (60 hemispheres) were obtained from routine autopsies. Cerebral arteries were separately cannulated and injected with colored latex. Then, the brains were fixed in formaldehyde, and dissections were performed using a surgical microscope. The diameter of the arterial branches supplying the splenium of the CC at their origin was investigated, and the vascularization patterns of these branches were observed. Vascular supply to the splenium was provided by the anterior pericallosal artery (40%) from the anterior circulation and by the posterior pericallosal artery (88%) and posterior accessory pericallosal artery (50%) from the posterior circulation. The vascularization pattern of the splenium differs in each hemisphere and is usually supplied by multiple branches. The arterial vascularization of the splenium of the CC was studied comprehensively considering the ongoing debate and the inadequacy of the studies on this issue currently available in the literature. This anatomical knowledge is essential during the treatment of pathologies in this region and especially for splenial arteriovenous malformations. Clin. Anat. 25:000–000, 2012.

Key words: corpus callosum; splenium; arterial vascularization; brain; cadaver

INTRODUCTION

The corpus callosum (CC) is the largest commissural tract and connects the two equal centers of the cerebral hemispheres. It is located at the base of the fissura longitudinalis cerebri; thus, the upper face of the CC can be seen when the two hemispheres are separated. Its shape and thickness can only be seen in sagittal brain sections. The CC, which connects the two cerebral hemispheres in all sections, is the main connection tract (Carpenter 1991; Williams 1995). The CC is divided into four parts from front to rear, as the rostrum corporis callosi, genu corporis callosi, truncus corporis callosi, and splenium corporis callosi. The splenium corporis callosi is the thick rear portion of the CC (Fitzgerald and Follan-Curran, 2002).

The anatomy of the CC is vital for neurosurgeons, anatomists, and clinicians because it is the primary commissural tract and is involved frequently in many pathologies and surgical interventions. It is used frequently by neurosurgeons for intraventricular lesions (Winkler et al., 2000), epilepsy procedures such as callosotomy (Gonçalves-Ferreira et al., 1995),

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TABLE 1. Sites of Origin of the APA[a]

	Right		Left		Total	
APA	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD
A2	0		1	1.62	1	1.62
A3	1	0.80	1	0.78	2	0.79 ± 0.01
A4	4	0.51 ± 0.015	3	0.56 ± 0.03	7	0.53 ± 0.03
A5	8	0.34 ± 0.017	6	0.42 ± 0.046	14	0.37 ± 0.051
Total	13	0.43 ± 0.144	11	0.62 ± 0.371	**24**	**0.53 ± 0.31**

[a]*n*: number; mean ± SD: diameter mean ± standard deviation in mm.

vascular pathologies such as distal anterior cerebral artery (ACA) aneurysms (Traynelis and Dunker 1992; Kawashima et al., 2003), and especially arteriovenous malformations (AVMs) of the splenium (Yaşargil et al., 1976; Barrow and Dawson, 1994). Despite the CC being a frequently accessed anatomical structure, it cannot be claimed that its vascular structure has been shown in detail. Studies on the vascular and arterial structure of this field are few, and the results have been sometimes inconsistent (Perlmutter and Rhoton, 1978; Türe et al., 1996; Kakou et al., 2000).

It is known that the arterial supply of the splenium is provided by the branches of the ACA and posterior cerebral artery (PCA). These branches are the anterior pericallosal artery (APA), posterior pericallosal artery (PPA), and posterior accessory pericallosal artery (PAPA) (Perlmutter and Rhoton, 1978; Zeal and Rhoton, 1978; Kakou et al., 1998; Kakou et al., 2000; Rhoton, 2002). Vascular supply of the CC, and of the splenium as a part of it, was studied in detail by Türe et al. (1996). In their study, the presence of the PPA and its primary importance in the blood supply of this region were demonstrated in all hemispheres. Additionally, they described a very thin artery arising from one of the branches of the PCA that contributes to the blood supply of the splenium, identified as the ''accessory posterior pericallosal artery.'' However, their study showed some inconsistencies from other studies with respect to certain points.

It would be difficult to claim that there is a clear study demonstrating the relationship of these structures. Further, to the best of our knowledge, there are no studies in the literature on the blood supply of these regions that are comparable and report consistent results. The inconsistency of the findings and lack of detailed demonstration of the relation of the arteries supplying these regions increase the likelihood of damage to these structures and thus to the patient during operations specifically concerning these areas. As a result, there is a great need to illustrate more clearly the relations between these structures and to demonstrate the arterial structures involved in the blood supply of this region, which holds vital clinical and surgical implications.

An intervention performed in any region of this tract can lead to serious complications, starting with problems in interhemispheric transfer and information transfer, by damaging the vascular structures found here (Fitzgerald and Follan-Curran, 2002; Devinsky and Laff, 2003; Clarke et al., 2007). Therefore, we consider that knowledge of the arterial supply patterns of each CC section, individually or as a whole, is of vital importance.

The aim of this study was to describe the arterial anatomy of the splenium in detail and to emphasize the clinical importance of any pattern differences.

MATERIALS AND METHODS

This study was conducted on 30 fresh human brains (60 hemispheres) obtained from autopsies at the Department of Anatomy, Faculty of Medicine, Ankara University. Brains with central nervous system disease or trauma were not included in this study. In all brains, both the internal carotid artery (ICA) and basilar artery were cannulated and washed with warm water under constant pressure and injected with colored latex. All dissections were performed under a microscope (Opmi 99, Carl Zeiss, Göttingen, Germany). The number, diameters, and sites of origin of the arteries that supply the splenium were evaluated during the study. Measurements of external diameters were made with 0.01 mm precision calipers by the first author.

All morphometric measurements are expressed as mean ± standard deviation (SD). Mean, median, and SD were used for the descriptive statistics. The differences between the diametrical measurements of the APA, PPA, and PAPA on the same side were evaluated by Kruskal–Wallis test and multiple comparisons test (Conover, 1980). Diametrical differences of the three arteries between the right and left sides were evaluated using Wilcoxon Signed Ranks test. Statistical analysis was performed using the Statistical Package for the Social Sciences 11.5. A P value less than 0.05 was considered significant.

RESULTS

Arterial vascularization of the splenium is primarily provided by three groups of arteries.

Anterior Pericallosal Artery

This branch arises from the A2, A3, A4, or A5 segment of the ACA and supplies the splenium after encircling the CC. It originated from A5 in 58.3%, A4 in 29.1%, A3 in 8.3%, and A2 in 4.1%. It originated from A2 in only one sample, and its diameter was 1.62 mm at the point of origin (Table 1). The APA originated from A3 in two hemispheres, with an average diameter of 0.79 mm. It originated from A4 in seven hemi-

TABLE 2. Sites of Origin of the PPA[a]

	Right		Left		Total	
PPA	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD
TO	2	0.45 ± 0.056	2	0.42 ± 0.028	4	0.43 ± 0.021
CA	1	0.72	4	0.47 ± 0.059	5	0.59 ± 0.18
PO	15	0.53 ± 0.055	13	0.65 ± 0.58	28	0.59 ± 0.08
PMCA	2	0.74 ± 0.042	2	0.76 ± 0.56	4	0.75 ± 0.014
P3	7	0.92 ± 0.029	5	0.89 ± 0.029	12	0.90 ± 0.021
Total	27	0.65 ± 0.183	26	0.66 ± 0.155	**53**	**0.65 ± 0.13**

[a]*n*: number; mean ± SD: diameter mean ± standard deviation in mm.
TO, temporooccipital artery; CA, calcarine artery; PO, parietooccipital artery; PMCA, posteromedial choroidal artery.

spheres, with an average diameter of 0.53 mm. It most frequently originated from A5 (14 hemispheres) with approximately half of the APAs derived here, with an average diameter of 0.37 mm. In general, the APA was observed in 24 hemispheres (40%) with an average diameter of 0.53 mm (Table 1) (Figs. 1–4).

Posterior Pericallosal Artery

This branch originated from the PCA. It most commonly originated from the cortical branches of this artery derived from the P4 segment. Among these cortical branches, it originated from the parietooccipital artery (PO) in more than half of the samples. It originated from this artery in 28 hemispheres, with an average diameter of 0.59 mm (Table 2). It originated from the temporooccipital artery (TO) in four hemispheres, from the calcarine artery (CA) in five hemispheres, and from the posteromedial choroidal artery (PMCA) in four hemispheres. The PPA had an average diameter of 0.43 mm, 0.59 mm, and 0.75 mm, respectively, when derived from each of these branches. It originated from the P3 segment of the PCA in 12 hemispheres, with an average diameter of 0.90 mm. The PPA is the primary artery responsible for the splenium supply. It was observed in 53 hemispheres (88%) in total, and the average diameter was 0.65 mm (Table 2) (Figs. 1, 2, 4, and 5).

Posterior Accessory Pericallosal Artery

This branch also originated from the PCA. In addition to being smaller than the PPA, the site of origin was also different ($P < 0.001$). It originated from the PO in approximately half of the hemispheres (16 hemispheres), with an average diameter of 0.31 mm. It originated from the PMCA in nine hemispheres and from the posterolateral choroidal artery (PLCA) in five hemispheres, with average diameters of 0.26 mm and 0.28 mm, respectively, when it originated from these rami. The PAPA was observed in half of the dissected preparations (30 hemispheres), and the average diameter was 0.29 mm (Table 3) (Figs. 1 and 4).

No statistical difference was found between the diameters of the APA, PPA, and PAPA on the right versus left side ($P > 0.05$). However, differences in the diameters of the three arteries on the same side were statistically significant ($P < 0.001$) (Table 4).

DISCUSSION

Vascular supply to the anterior parts of the CC by similar arterial groups, the clinical significance of these supplying structures (Kahilogullari et al., 2008), and the effect of the ACA in this region (Ugur et al., 2006) have been described previously. However, the splenium differs from the other parts of the CC with respect to both the vascular nutritional pattern and clinical and surgical approaches. Although the rostrum, genu, and trunk, which constitute the anterior part of the CC, are supplied by branches of the artery coming from the anterior circulation, the splenium, unlike some of these sections, is supplied by both anterior and posterior branches of the artery (Türe et al., 1996). Just as the splenium differs from the anterior parts of the CC in terms of vascular supply, it is also distinct in terms of clinical and surgical approaches. Although the CC areas mentioned above are in the foreground in surgical approaches, such as for vascular pathology (Kosary et al., 1978) or pathologies requiring callosotomy (Lozier and Bruce, 2003) [i.e., posterior tumors of the lateral ventricle (Wang et al., 2010) or tumors of the pineal region (Hancq et al., 2002)], the splenium has been considered (Moshel et al., 2009). It should be kept in mind that one of the most important and specific pathologies in this region is AVM, an abnormal collection of blood vessels in which blood from arteries in the brain flows directly into draining veins without the normal intervening capillaries. In this case, a precise anatomical knowledge of the arteries is essential during surgical intervention for AVMs involving the splenium (Barrow and Dawson, 1994).

Several studies have reported on the vascular supply of the splenium (Zeal and Rhoton, 1978; Yamamoto and Kageyama, 1980; Milisavljevic et al., 1986; Timurkaynak et al., 1986; Türe et al., 1996). Although presence of the PPA and its primary importance for blood supply of this region were demonstrated by Yamamoto and Kageyama (1980) at a rate of 62.8% and by Türe et al. (1996) at a rate of 100%, this rate was 88% in our study. The anastomosis rate between the PPA and APA within the splenium region was reported as 75% by Milisavljevic et al. (1986) and as 100% by Türe et al. (1996) and Zeal and Rhoton (1978). In our study, we determined that the splenium was supplied by the APA in 40%, and anastomosis with the PPA was always

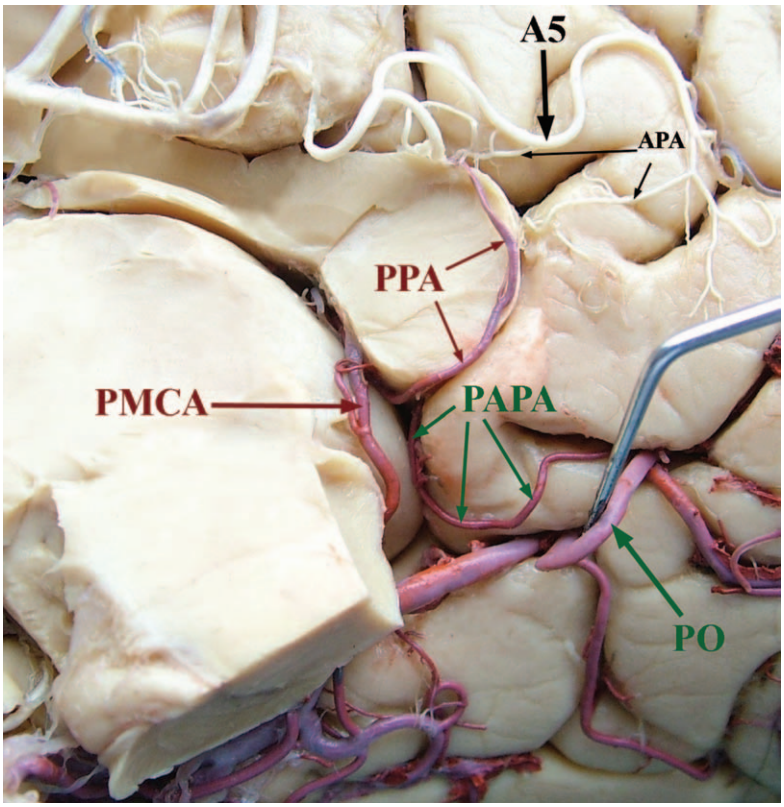

Fig. 1. Supply to the splenium of the CC in the right hemisphere of a dissected brain on the sagittal plane. APA (thin black arrows) originated from A5 (thick black arrow), PPA (thin red arrows) originated from PMCA (thick red arrow), and PAPA (thin green arrows) originated from PO (thick green arrow). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

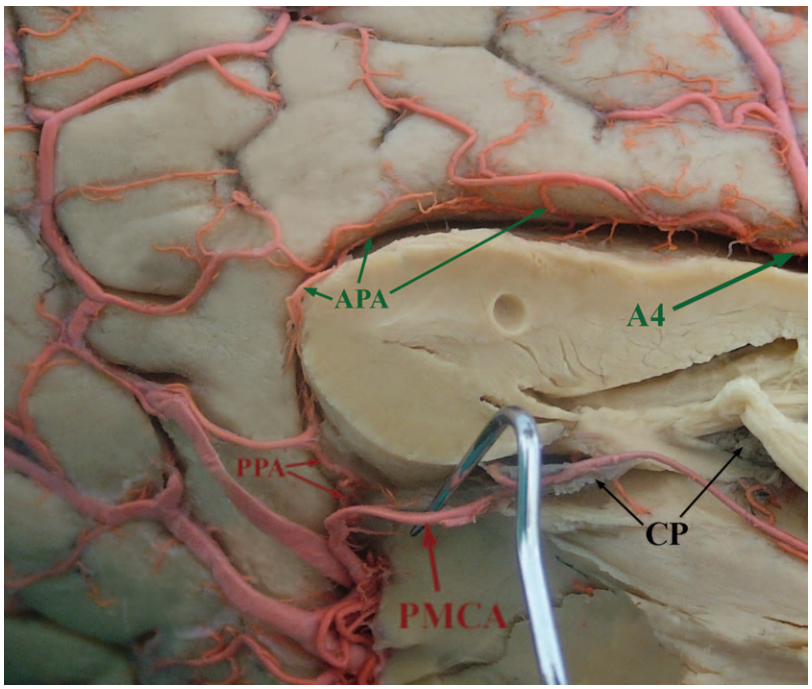

Fig. 2. Supply to the splenium of the CC in the left hemisphere of a dissected brain on the sagittal plane. PPA (thin red arrows) originated from PMCA (thick red arrow) progressing toward the CP (choroid plexus—black arrow), and APA (green arrows) originated from the A4. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Fig. 3. Supply to the splenium of the CC in the left hemisphere of a dissected brain on sagittal plane by an APA intensively originated from A4 (thick red arrow). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Fig. 4. Illustration of the arteries of the splenium in a left hemisphere: APA, PPA, PAPA, CP (choroid plexus), A4 (ACA-A4 segment), AP (anastomosis point between APA and PPA), PO, and PMCA. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

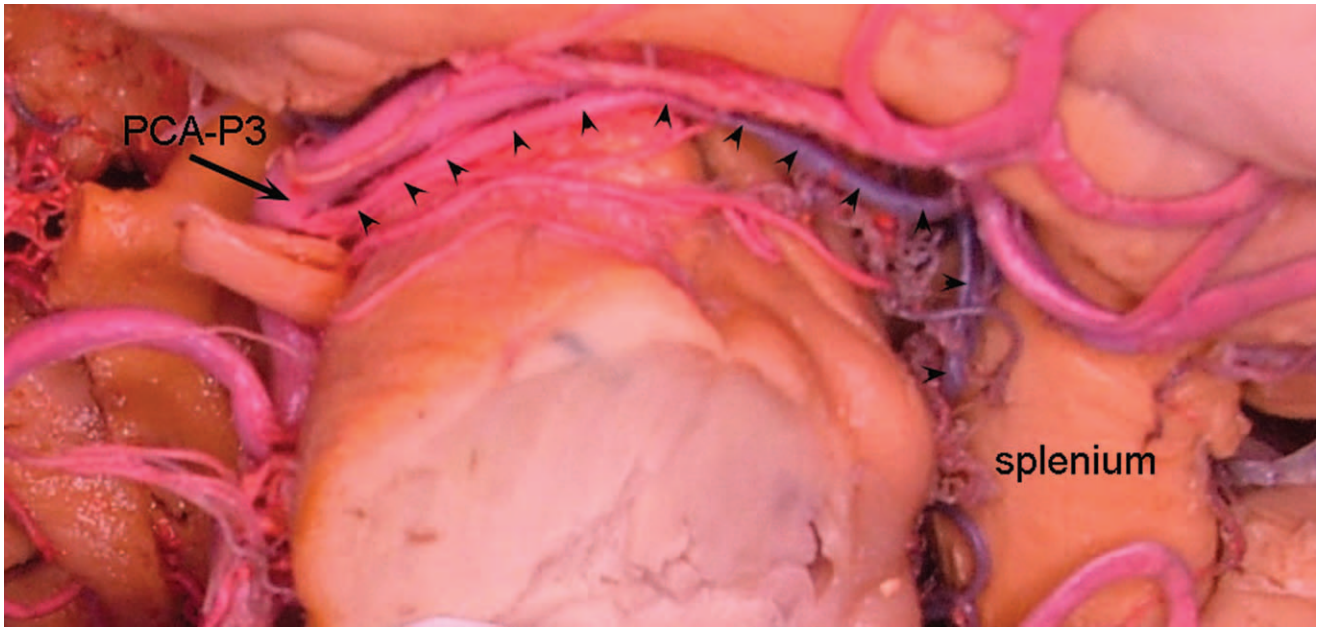

Fig. 5. Supply to the splenium of the CC in the left hemisphere (basal view) by a PPA (black arrows) originated from P3. PCA-P3 (posterior cerebral artery-P3 segment). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

TABLE 3. Sites of Origin of the PAPA[a]

	Right		Left		Total	
PAPA	*n*	Mean ± SD	*n*	Mean ± SD	*n*	Mean ± SD
PO	8	0.32 ± 0.051	8	0.31 ± 0.045	16	0.31 ± 0.01
PMCA	6	0.30 ± 0.042	3	0.22 ± 0.014	9	0.26 ± 0.06
PLCA	2	0.28 ± 0.042	3	0.28 ± 0.043	5	0.28 ± 0.00
Total	16	0.30 ± 0.045	14	0.27 ± 0.50	**30**	**0.29 ± 0.04**

[a]*n*: number; mean ± SD: diameter mean ± standard deviation in mm.
PO, parietooccipital artery; PMCA, posteromedial choroidal artery; PLCA, posterolateral choroidal artery.

TABLE 4. Measurements of the Diameters of the Three Main Arteries (APA, PPA, and PAPA) on Both Sides

	APA		PPA		PAPA		
	n	Mean ± SD (median)	*n*	Mean ± SD (median)	*n*	Mean ± SD (median)	*P*
Right	13	0.43 ± 0.14 (0.35)	27	0.65 ± 0.18 (0.57)	16	0.31 ± 0.05 (0.32)	$P < 0.001$[a]
Left	11	0.62 ± 0.37 (0.51)	26	0.66 ± 0.16 (0.65)	14	0.28 ± 0.05 (0.28)	$P < 0.001$[a]
P		$P > 0.05$		$P > 0.05$		$P > 0.05$	

[a]When compared on the same side, the differences were statistically significant.

present (anastomosis between these two groups of arteries was also present in 40%.) Türe et al. (1996) indicated that the PPA, also known as the splenial artery, supplies the splenial part of the CC in each hemisphere. It was indicated that this branch originated from the PO in 52%, P3 in 7%, and CA in 7%. Moreover, Rhoton (2002) indicated that this artery originated from the PO, CA, posterior temporal artery, PMCA, and PLCA, but the corresponding rates were not shown. Yamamoto and Kageyama (1980) reported that they observed the PPA in 62.8% in their study of 30 brains, and this artery originated from the PO in 31.4%, CA in 17.2%, PLCA in 8.6%, PMCA in 2.8%, and common temporal artery in 2.8%. In our study, the PPA was detected in 88%, and originated from the PO in 52.8%, P3 in 22.6%, CA in 9.4%, and TO in 7.5%. We distinctively detected that it also originated from the PMCA, which

was not specified previously, in 7.5%. The average diameter reported previously was 0.7 mm, and this was approximately the same in our study, calculated as 0.65 mm. However, when it originated from P3, the diameter was significantly thicker (0.90 mm). Türe et al. (1996) described the three anatomical variations according to separation of the PPA as behind or under the splenium and then encircling it. Accordingly, there are three types, designated as proximal, distal, and mixed. In all types, it was emphasized that the PPA is divided into two branches and supplies the splenium. It was also indicated that, from this artery, a smaller branch, seen at a rate of 25%, supplies the splenium, and this ramulus was referred to as the PAPA. However, that report did not characterize the grouping of the ramulus, APA and PPA, their places in the typology mentioned above, or their relationship with each other. In this study, the relations of this artery group, their origins, and the frequencies of occurrence in the splenium were evaluated. Our focus was determining the patterns of vascular supply in the splenium of the three artery groups supplying this region rather than the typing of the PPA. The PAPA was seen in 50% of the specimens in our study. Türe et al. (1996) detected its average diameter as 0.3 mm and showed the sites of origin as the PO, hippocampal artery, PMCA, and PLCA, without specifying the rates. The average diameter was similar to that in our study, and it originated from the PO in 53.3%, PMCA in 30%, and PLCA in 16.6%. Different from the studies published previously, our study defines the rates for each point of origin and the associated diameters of the APA at each point of origin in detail.

CONCLUSIONS

In this study, we determined that the splenium is supplied by branches of the APA from the anterior circulation (40%), whereas the posterior circulation is supplied from the PPA (88%) and PAPA (50%). Using this arterial anatomical knowledge, pathologies of this region that involve the splenium, especially AVMs, can be treated properly and safely. Additionally, one might theorize that with the advent of new technologies, selective intravascular treatment will be possible in the future by intervention via arteries of the splenium.

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