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ORIGINAL PAPER

Arterial vascularization of the pineal gland

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Abstract
Purpose The arterial vascularization of the pineal gland (PG) remains a debatable subject. This study aims to provide detailed information about the arterial vascularization of the PG.
Methods Thirty adult human brains were obtained from routine autopsies. Cerebral arteries were separately cannulated and injected with colored latex. The dissections were carried out using a surgical microscope. The diameters of the branches supplying the PG at their origin and vascularization areas of the branches of the arteries were investigated.
Results The main artery of the PG was the lateral pineal artery, and it originated from the posterior circulation. The other arteries included the medial pineal artery from the posterior circulation and the rostral pineal artery mainly from the anterior circulation. Posteromedial choroidal artery was an important artery that branched to the PG. The arterial supply to the PG was studied comprehensively considering the debate and inadequacy of previously published studies on this issue available in the literature.
Conclusions This anatomical knowledge may be helpful for surgical treatment of pathologies of the PG, especially in children who develop more pathology in this region than adults.

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Introduction

The pineal gland (PG) is arterialized by branches deriving from the ACA (anterior cerebral artery) and PCA (posterior cerebral artery). Studies regarding the arterial vascularization of the PG have been carried out on animals [1–5] and on humans by Duvernoy [6], who named the arteries but did not explain their percentage, origin, or relationship to each other.

The lack of knowledge in this field contributes to the likelihood of complications occurring during surgery in this area. This emphasizes the necessity of showing these feeding arteries and the relationship between them in this clinically and surgically important area. The aim of this study was to take a broad overview of the venous ultrastructure and arterial supply of the PG and the pineal region, in which many pathological conditions can occur. It was also aimed to show the relationship between these arteries and during surgical procedures. This knowledge is even more essential in the pediatric age group, in which pathologies of this region are shown to occur more often.

Materials and methods

This study was conducted on 30 human brains provided by autopsy material at Ankara University Faculty of Medicine, Department of Anatomy. Subjects with central nervous system disease or who had been exposed to a trauma were excluded. All the brains were first cannulated using saline solution under stationary pressure from the internal cerebral

Table 1 Sites of origin of the LPA

LPA	Right		Left		Total	
	n	Mean±SD	*n*	Mean±SD	*n*	Mean±SD
SCA	2	0.24±0.28	1	0.23	3	0.24±0.02
PMCA	20	0.22±0.24	17	0.21±0.28	37	0.22±0.03
PLCA	1	0.20	2	0.20±0.14	3	0.20±0.01
Total	23	0.22±0.02	20	0.21±0.02	43	0.22±0.03

artery (ICA) and basilar artery, and after this procedure, they were recannulated from the ACA and ICA with latex solution. Following this step, all the brains were fixated in 10 % formaldehyde solution (Merck, KGaA, Germany). All the dissections were run under a surgical microscope (Carl Zeiss, Opmi 99, Germany). All the morphometric measurements were obtained by the same person using a 0.1 mm sensibility compass (BTS Digital caliper, 150X0.1 mm). In this study, the number, diameter, and origin of the arteries feeding the PG and the relationship between them are reported, and the clinical importance of this knowledge is noted.

Results

It was observed that the PG was vascularized by three arterial groups: the lateral pineal artery (LPA) and medial pineal artery (MPA), which derived consistently from the posterior circulation, and the rostral pineal artery (RPA), which was determined to originate from either posterior or anterior circulation.

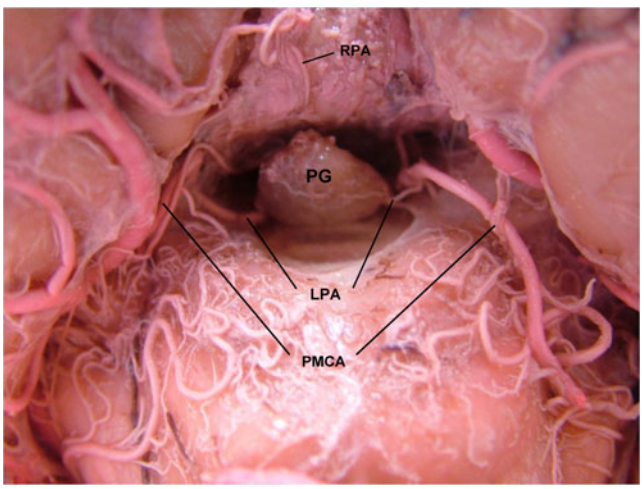

Fig. 1 Supply to the pineal gland (*PG*) in posterior view demonstrates: lateral pineal artery (*LPA*) originating from the posteromedial choroidal artery (*PMCA*) and supplying the PG bilaterally, and rostral pineal artery (*RPA*) supplying the superior aspect of the PG

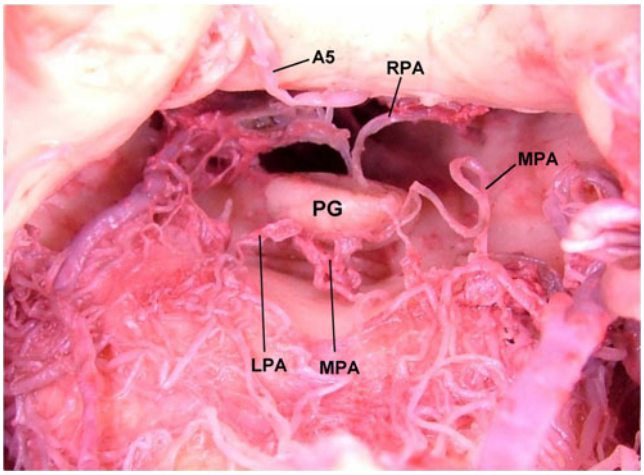

Fig. 2 Supply to the pineal gland (*PG*) in posterior view demonstrates: lateral pineal artery (*LPA*) supplying the left side of the PG, medial pineal artery supplying the apex of the PG with two branches, and rostral pineal artery supplying the superior aspect of the PG

Lateral pineal artery

Especially the lateral region of the PG was vascularized by branches deriving from the lateral side. In 37 (61 %) hemispheres, these derived from the posteromedial choroidal artery (PMCA), and the average diameter was 0.22 mm. Three (5 %) hemispheres showed arteries deriving from the superior cerebellar artery (SCA) and 3 (5 %) other hemispheres showed arteries deriving from the posterolateral choroidal artery (PLCA). The diameters of the arteries were 0.24 and 0.20 mm, respectively. Overall, for 43 (71 %) hemispheres, the LPA was the main artery providing the

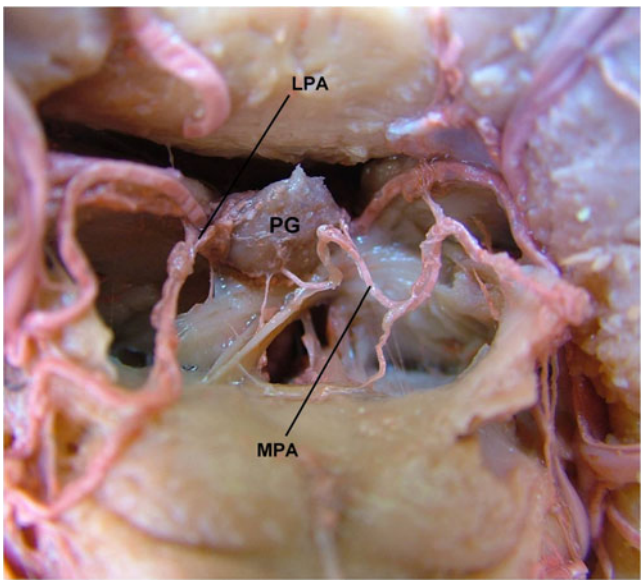

Fig. 3 Supply to the pineal gland (*PG*) in posterior view demonstrates: lateral pineal artery (*LPA*) supplying the left side of the PG, and medial pineal artery supplying the apex and inferior part of the PG

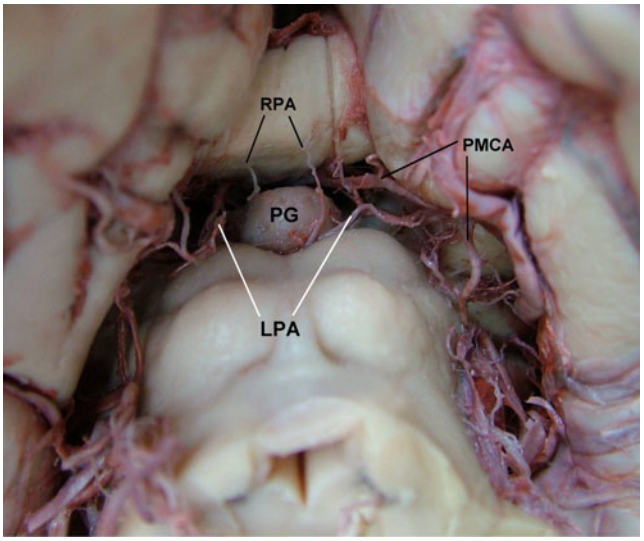

Fig. 4 Supply to the pineal gland (*PG*) in the posterior view demonstrates: lateral pineal artery (*LPA*) originating from the posteromedial choroidal artery (*PMCA*) supplying the PG bilaterally, and rostral pineal artery (*RPA*) originating from A5 supplying the superior aspect of the PG with two thin branches

arterial supply of the PG, and the mean diameter was 0.22 mm (Table 1) (Figs. 1, 2, 3, 4, 5, and 6).

Medial pineal artery

The MPA is formed by branches coursing through the midline and feeding the apex of the PG. This arterial group usually originates from the PMCA. In 18 (30 %) hemispheres, it derived from the PMCA, and in two (3 %) of the hemispheres, it derived from the SCA. The average diameters were 0.21 and 0.24 mm, respectively. In total, it was visualized in 20 (33 %) hemispheres, and the average diameter was 0.22 mm (Table 2) (Figs. 2, 3, 5, and 6).

Rostral pineal artery

These are arteries that course through the superior aspect of the PG and provide blood circulation. Unlike other arteries of the PG, these arteries derive more from the anterior than the posterior circulation. Most frequently, branches from the A5 segment of the ACA supplied the vasculature. In seven (11 %) of the hemispheres, arteries originated from branches from this segment, and in one (1.6 %) hemisphere, from the A4 segment. When originating from the A4 segment, the average diameter was 0.16 mm, while from the A5 segment, it was 0.17 mm. In the posterior circulation, four (6 %) branches derived from the PMCA, and one (1.6 %) branches originated from the P3 and afforded blood supply. The average diameters were 0.17 and 0.20 mm, respectively. This arterial distribution was visualized in 13 (21 %) hemispheres, and the general average was 0.17 mm (Table 3) (Figs. 2, 4, and 6).

The arteries of the PG were always present and numbered 2.5 (1–4). Eighty percent were bilateral (Figs. 1 and 4) and 20 % unilateral (Figs. 2 and 3). The most frequent arterial supply pattern was one bilateral artery, as found in ten

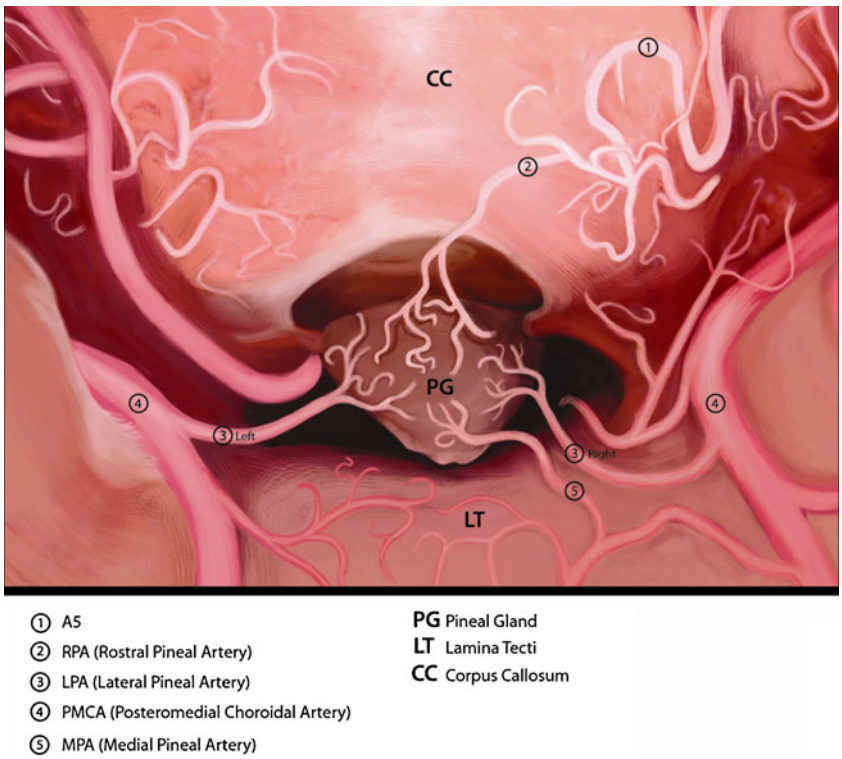

Fig. 5 Illustration of the arteries of the pineal gland in posterior view

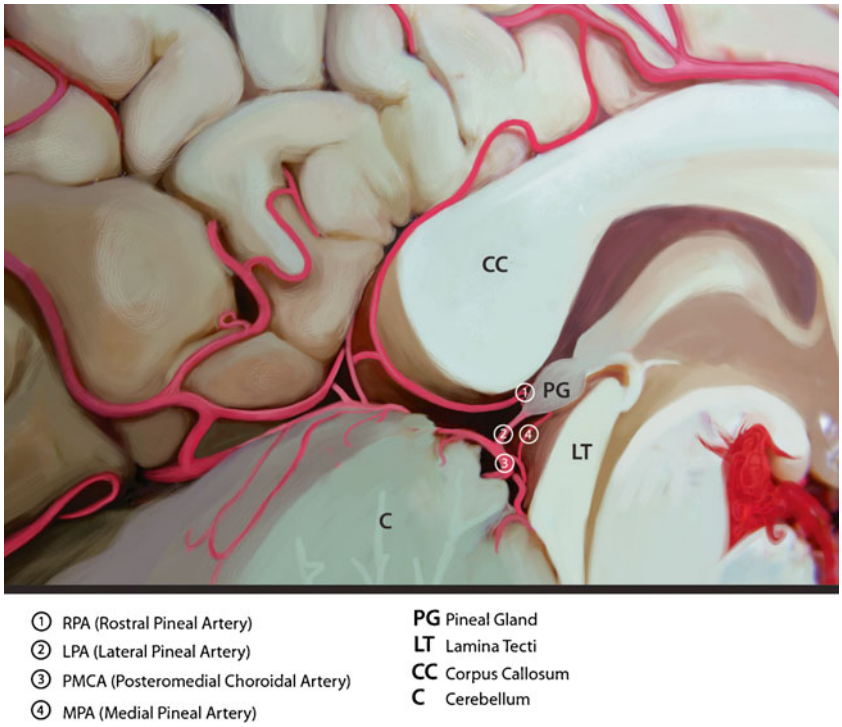

Fig. 6 Illustration of the arteries of the pineal gland in a left hemisphere on sagittal plane

samples (33 %). In six samples, the PG was vascularized from the right by two and from the left by one vessel. In case of unilateral vascularization, none of the vasculature was provided from the left (Table 4).

No statistical difference was found between the diameters of the LPA and MPA 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, and the diameter of the RPA was statistically smaller than that of the LPA and MPA ($p<0.01$) (Table 5).

Discussion

There are many pathologies and pathological conditions associated with the PG and its region. The tumors of this area altogether account for 0.4–1 % of all intracranial tumors [7–10]. The incidence is high in children, ranging between 3–11 % [11–14]. In adults, 60 % of pineal tumors are benign; however, 60–80 % in children are malignant [14, 15]. The most common tumors are pineal parenchymal and germ cell tumors [16]. A wide range of tumors is seen in this region, including cavernoma, pineal cyst, glial tumors, meningioma, papillary tumors, pancreatic adenocarcinoma metastasis, central neurocytoma, craniopharyngioma, sarcoidosis, cysticercosis, tuberculous abscess, choroid plexus papilloma, and glioblastoma [4, 8–10, 17–32]. Different surgical techniques have been described [8, 18, 33–36]. Less invasive techniques such as neuroendoscopy are preferred for surgical procedures of this region in cadavers and living subjects [37–42]. Advances in technology have facilitated the use of endoscopy and navigation techniques in surgical procedures of this region [23, 43]. All the minimally invasive procedures require full anatomical knowledge of this area.

The PG, which is visualized at the end of the corpus callosum, show similarities with the splenium with regard

Table 2 Sites of origin of the MPA

MPA	Right		Left		Total	
	n	Mean±SD	*n*	Mean±SD	*n*	Mean±SD
SCA	2	0.24±0.14	–	–	2	0.24±0.14
PMCA	11	0.21±0.21	7	0.21±0.26	18	0.22±0.02
Total	13	0.22±0.21	7	0.21±0.26	20	0.22±0.02

Table 3 Sites of origin of the RPA

RPA	Right		Left		Total	
	n	Mean±SD	*n*	Mean±SD	*n*	Mean±SD
A4	1	0.16	–	–	1	0.16
A5	4	0.17±0.03	3	0.18±0.02	7	0.17±0.03
PMCA	2	0.15±0	2	0.18±0.03	4	0.17±0.02
P3	–	–	1	0.20	1	0.20
Total	7	0.16±0.02	6	0.18±0.02	13	0.17±0.02

Table 4 Supply pattern of PG arteries

Right-number of supplying arteries	Left-number of supplying arteries	Number of artery	Percent of arteries
1	1	10	33 %
2	1	6	20 %
1	2	3	10 %
1	0	3	10 %
2	0	3	10 %
2	2	2	6 %
1	3	2	6 %
3	1	1	3 %

to the arterial supply [44]. The most comprehensive study on this subject can be found in the work of Duvernoy et al. [6]. However, the study presents some conflicting results when compared with other studies and has significant differences in artery denomination. For example, three main arteries have been reported for the arterial supply of the PG, as the PMCA and collicular (or quadrigeminal) artery from the posterior circulation and the posterior pericallosal artery originating from the anterior circulation [6]. However, in all previous studies, the term posterior pericallosal artery was used for the arterial group originating from the posterior circulation [45–48].

Arterial supply of the PG is provided mainly by branches deriving from the PMCA, and this has been reported by all the authors studying this region [46–49]. Yamamoto and Kageyama named this arterial group as the pineal artery [46]. They noted that it could be absent or reach up to five in number in one hemisphere and 1.5 on average, and they also reported it as bilateral in 70 % and unilateral in 30 %. This artery penetrated the PG from its lateral side. These ratios are similar to those of our study. Denomination of the arteries of the PG was made by Duvernoy et al. [6]. They showed three arterial groups originating from the PMCA supplying the PG. The first and main group was noted to be right and left pineal arteries, and these originated from the PMCA at the ambient cistern and coursed through the PG. In two cases, these arteries derived from collicular arteries instead of the PMCA. The second group was noted to consist of smaller branches and to originate from the PMCA at the quadrigeminal cistern. This second group was named as RPA and reported as feeding the lateral and posterior surfaces of the PG. The last of such arterial groups is the one observed the least, which originates from the PMCA and courses through the inferior surface of the gland, supplying the apex of the PG. The latter is denominated as the MPA. All the pineal arteries end at the pineal apex in a subpial manner. These authors did not report the ratio, diameter, or relationship between the branches of these arteries.

Precise knowledge of the anatomy of the surgical area in the pineal region and during PG surgeries is of vital importance. The venous vascular structures in this region are also of great significance [7–9, 14, 24, 30, 50]. It cannot be claimed at present that these studies have noted the anatomy of the arterial vasculature precisely, and as a result, many complications can occur due to arterial damage, with clinical outcomes [9, 14, 24, 25].

In our study, we found that the LPA provides the main supply of the PG. A rare pineal artery, the MPA mainly supplies the apex of the gland. The other rare artery, the RPA, supplies the superior portion of the gland. In consequence, the PG is mainly supplied by the LPA, and its lateral portions are more susceptible to arterial injury. Based on this knowledge [7–9, 18, 24, 33–36], the anatomic ultrastructure of these arteries is essential in surgical procedures of this region as well as in such scientific investigation on animals, such as pinealectomy [51], which also has effects on the spinal cord.

Conclusions

This is the first detailed report on the arterial vascularization of the PG. We found that the PG is supplied by both the anterior and posterior circulation. The main artery supplying

Table 5 Measurements of the diameters of the three main arteries (LPA, MPA, RPA) on both sides

	LPA		MPA		RPA		*p* value
	n	Mean±SD	*n*	Mean±SD	*n*	Mean±SD	
Right	23	0.22±0.02	13	0.22±0.21	7	0.16±0.02	$p<0.01$[a]
Left	20	0.21±0.02	7	0.21±0.26	6	0.18±0.02	$p<0.01$[a]
p value	$p>0.05$	$p>0.05$	[b]				

(*LPA* lateral pineal artery, *MPA* medial pineal artery, *RPA* rostral pineal artery, *PMCA* posteromedial choroidal artery, *SCA* superior cerebellar artery, *PLCA* posterolateral choroidal artery, *PG* pineal gland)

[a] When compared on the same side, the differences were statistically significant; RPA diameter was statistically smaller than that of the LPA and MPA

[b] In this group, '*n*' was not sufficient for statistical evaluation

the PG was the LPA, which always originated from the posterior circulation. For this reason, midline approaches may be suitable in surgery (microscopic, endoscopic, etc.) in this region in terms of preserved arterial supply of the gland. Other suppliers of the gland were the MPA, which was found to originate from the posterior circulation, and the RPA, which mainly originated from the anterior circulation. The arteries of the PG mainly originated from the PMCA, and any damage to this vessel could cause catastrophic problems within the gland. In surgical procedures of this region, the venous anatomy of the PG in the pineal region as well as the arterial ultrastructure should be well known, especially in the pediatric age group, since it more susceptible to pathologies in this region. Such knowledge should elicit effective and better results.

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