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Diversity among posterior thalamoperforating branches originated from P1 segment: systematic review

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Background: *The P1 segment of the posterior cerebral artery (PCA) begins at the termination of the basilar artery and ends at the origin of posterior communicating artery, within the interpeduncular cistern. Perforating branches arising from this segment are called posterior thalamoperforating arteries (TPAs) and the main and biggest artery among those is called TPA. Perforating branches are a crucial component of cerebrovascular system supplying the posterior part of the thalamus, subthalamus, hypothalamus, substantia nigra, perforated substance, posterior part of internal capsule and the nucleus of III and IV cranial nerve. It is very important for neurosurgeon to know the anatomy of perforating branches because of their susceptibility to injury. The aim of this study is to determine the morphometry of posterior TPAs and allow a better understanding of their branching patterns and relation to basilar artery.*

Materials and methods: *An extensive search was undertaken in order to identify published literature related to the posterior cerebral circulation system and the anatomy of posterior TPAs using key words. Medline, Embase, Ovid and Google Scholar databases were searched for publications dated from 1970 until July 2016. We collected and analysed all the data describing the mean number of branches per P1 segment, range of branches, number of analysed PCA, largest diameter of TPA, mean diameter of TPA and average distance from the basilar artery bifurcation.*

Results: *Thirteen cadaver studies were analysed and the data was extracted. We focused on the mean number of branches arising from P1 segment, perforators range, mean diameter of perforating branches, largest diameter of perforating branches.*

Conclusions: *Mean number of branches per hemisphere was 2.91 (min. 1.51, max. 4.1). In more than half of analysed studies, authors did not find any presence of posterior TPAs. Mean diameter of those perforators was 0.51 mm (min. 0.125 mm, max. 0.8 mm). Average distance from basilar artery bifurcation was 2.29 mm (min. 1.93 mm, max. 2.75 mm). There were many branching patterns presented by different authors.* (Folia Morphol 2017; 76, 3: 335–339)

Key words: thalamoperforating artery, posterior cerebral artery, P1 segment, perforating branches

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INTRODUCTION

In 1968 Krayenbuhl and Yasargil [9] first proposed dividing posterior cerebral artery into four segments. The P1 segment starts from the end of basilar artery bifurcation and ends at the origin of posterior communicating artery stem. The P2 segment is the part of the artery, which is coursing around the cerebral peduncle and ends when the pulvinar is reached. We distinguish the anterior part of the artery called P2a and the posterior part of the artery called P2p. The P3 segment runs from the pulvinar to the calcarine sulcus. The P4 segment consists of the cortical branches expanding from the main stem of the artery.

Posterior thalamoperforating arteries (TPAs) are small vessels originating from the P1 segment of posterior cerebral artery (PCA). Among many anatomical cadaveric studies we can find different names given by the authors. Lazarothes and Salamon [12] described them as the inferior thalamic arteries, Percheron [20] as paramedian thalamo-subthalamic arteries, Pedroza et al. [18] as the paramedian thalamic arteries. TPA were firstly described by Duret [4] and Heubner [7] at the end of 19th century and called as "optic arteries". Those perforating branches are supplying the posterior perforated substance, interpeduncular fossa, posterior part of the thalamus, hypothalamus, subthalamus, substantia nigra, red nucleus, oculomotor nucleus, reticular formation of the midbrain, posterior part of the internal capsule and pretectum. TPAs enter the brain through the posterior perforated substance and then run through interpeduncular fossa and medial cerebral peduncles [9, 11, 24]. In case of TPA injury patient may suffer from cerebellar ataxia, contralateral hemiplegia, hemibalismus, rubral tremor or oculomotor nerve paresis. Many perforating branches supply the cisternal part of the oculomotor nerve and occlusion of one of those vessels may result with nerve dysfunction. The surgical treatment of aneurysms and arteriovenous malformations should be thoroughly analysed when situated in the posterior part of cerebral circulation, especially close to the cisternal segment of the oculomotor nerve in order not to close the thalamoperforating branches. Occluding those arteries may also result with lacunar infarct. The aim of this study is to determine the morphometry of posterior TPAs and allow a better understanding of their branching patterns and relation to basilar artery. Arteries are also a crucial landmark of brain anatomy; therefore, this knowledge will allow the surgeon to reduce the probability of complication occurrence.

MATERIALS AND METHODS

Literature search strategy

PubMed, Embase, Ovid, Google Scholar databases were searched by author (CG). The key words: "thalamoperforating arteries", "posterior cerebral circulation", "PCA branches" were used. The search period was limited to the studies published between 1970 and July 2016. The reference list of every reviewed article was analysed for potentially useful studies.

Selection criteria

Selection of studies for this systematic review included only cadaveric studies. The language of the studies was multi-lingual. Abstracts, conference presentations, case reports were excluded. We searched for studies that contained the mean number of perforating branches per P1 segment and minimal and maximal number of perforating branches that originated from P1 segments. We also managed to extract very important data not presented in every study.

Interpretation of studies

Extracted data is presented in tables and sorted according to the year of published paper. Apart from data mentioned earlier we also managed to compare the largest diameter of perforating branches, mean diameter of TPA and average distance from the basilar artery bifurcation. Also the branching pattern and P1 segment surface that was the origin of the perforators was analysed.

RESULTS

Mean TPAs number and range

In 6 of presented studies, authors did not find any posterior TPAs. The biggest number of those vessels was 13 branches per hemisphere. The mean number of branches per hemisphere was usually bigger than 2 except the study presented by Rassi et al. [21], where the mean branch number equalled 1.51. He also reported that the mean branch number was bigger in males (1.66 per hemisphere) than females (1.36 per hemisphere). Studies performed by Saeki et al. [23] in 1977 and Caruso et al. [2] in 1990 included the analysis of 100 hemispheres. The results concerning mean branch number per hemisphere were similar. Study performed by Saeki and Rhoton [23] presented that the mean branch number per hemisphere equalled 4 and in study made by Caruso et al. [2] — 4.1. The range of branches in the mentioned studies was almost the same as we can see in Table 1.

Table 1. Mean branch number per hemisphere and range of posterior thalamoperforating arteries

Study	No. of hemispheres	Mean branch number per hemisphere	Range
Saeki, 1977 [23]	100	4	1–13
Zeal, 1978 [27]	50	2.7	0–8
Marinkovic, 1986 [14]	14	2	1–10
Caruso, 1990 [2]	100	4.1	0–13
Rassi, 1992 [21]	60	1.51	0–4
Cosson, 2003 [3]	24	3.75	2–5
Uz, 2007 [25]	30	2	0–5
Pai, 2007 [15]	50	2	0–4
Kaya, 2009 [8]	28	3.35	0–8
Park, 2010 [16]	52	3.6	1–8
Parraga, 2011 [17]	70	3	1–10

Table 2. Mean diameter of posterior thalamoperforating arteries and largest diameter of posterior thalamoperforating arteries

Study	Mean diameter	Largest diameter
Saeki, 1977 [23]	0.8 mm	1.6 mm
Zeal, 1978 [27]	0.6 mm	1.2 mm
Marinkovic, 1986 [14]	0.321 mm	Not available
Pedroza, 1986 [18]	0.63 mm	1.1 mm
Caruso, 1990 [2]	0.125 mm	1.2 mm
Rassi, 1992 [21]	0.43 mm	Not available
Park, 2010 [16]	0.7 mm	1.18 mm

Mean diameter of posterior TPA

The lowest mean diameter is presented in the study carried out by Caruso et al. [2] and equals 0.125 mm among 100 hemispheres that were analysed, however as we can see the highest mean diameter, that equals 0.8 mm is presented by Saeki and Rhoton [23], where 100 hemispheres were analysed as well. The results are different as opposed to the previous analysed factor, where the results were similar. The largest diameter of posterior TPAs was presented by Saeki and Rhoton [23] and equalled 1.6 mm. We calculated the mean largest diameter, which equals 1.26 mm. The results regarding the largest diameter found in other studies were similar as we can see in Table 2. The mean diameter of P1 segment perforators in every study is lower than 1 mm, which is essential.

Branching patterns

After analysis of gathered data we came to a conclusion that five different branching patterns can be described [16]. Type I consists of bilateral multiple branches, Type II has multiple branches originating from one P1 segment and one branch originating from the other P1 segment, Type III has bilateral single branches, Type IV consists of unilateral multiple branches and Type V has unilateral single branch. Type V was the least common pattern among presented studies. Lang and Brunner [10] as well as Rassi et al. [21] discovered that single unilateral perforating vessel originating from one hemisphere perforates and supplies also the other hemisphere. The data describing branching patterns was diversified among presented studies. Type III (single stem, bilateral) was the most common in studies presented by Lang and Brunner [10], Pedroza et al. [18] and Uz [25].

DISCUSSION

Posterior TPAs are small vessels, usually less than 1 mm in their diameter, running from P1 segment. According to many studies those arteries originates from posterior, superior or posterior-superior part of the P1 segment [5, 7, 8, 15–17, 22, 23, 25, 27] except in study performed by Caruso et al. [2]. In their research perforators originated from posterior or inferior part of P1 segment. Usually the artery with the largest diameter is the main perforator called the posterior TPAs, and sometimes can be an origin of medial posterior choroidal arteries. According to studies performed by Rhoton

Jr. [22] and Zeal and Rhoton [27] in 56% of all cases the closest branch to the basilar artery bifurcation is the main stem of the TPAs complex and originates from the proximal part of the P1 segment. In Table 3 we have presented the distance measured from the basilar artery bifurcation to the first observed perforating branch.

Kaya et al. [8] confirms that in their study TPAs was the most proximal branch among all perforators. According to Marinkovic et al. [13, 14] TPAs can originate from P2 segment, which took place in 3.3% of all cases in their study, and from the posterior communicating artery in 6.6% of all cases. Hara and Fujino [6] found posterior TPA originating directly from the basilar artery. Saeki and Rhoton [23] reports that in in 8% of all cases TPAs arose 1 mm from medial part of P1 segment, 5% of all arteries arose from the lateral part and in 87% of all cases it arose from the central part of P1 segment.

The branching pattern of TPAs is vastly differentiated. Percheron [20] in his study described three types of vascular configuration: Type I, when one stem arose from each P1 segment, Type II when vessels arose unilaterally and Type III is described as arterial arcade connecting both P1 segments. In his study Type I was present in 32% of all specimens, Type II in 28% and Type III in 3% of all cases. Percheron [19] also pointed that perforators can arise only from one side, which was confirmed by Lang and Brunner [10], Pedroza et al. [18], Rassi et al. [21], Westberg [26] and Park [16]. Lang and Brunner [10] as well as Rassi [21] noted that perforators arising only from one side can supply the opposite hemisphere, which happened in 8% of cases [10] and 6.66% of cases [21].

Table 3. The average distance between the basilar artery (BA) bifurcation and nearest thalamoperforating branch

Study	BA bifurcation average distance
Saeki, 1977 [23]	2.2 mm
Marinkovic, 1986 [14]	2.1 mm
Pedroza, 1986 [18]	2.75 mm
Rassi, 1992 [21]	2.47 mm
Park, 2010 [16]	1.93 mm

Pedroza et al. [18] classified the origin pattern into six groups. Group 1 was described as unilateral single trunk and occurred in 3 brains, Group 2 described as bilateral single trunk (8 brains), Group 3 described as unilateral double trunk (3 brains), Group 4 described as bilateral single trunk on the one side and double trunk on the other side (10 brains), Group 5 described as double bilateral (2 brains) and Group 6 described as multiple unilateral (2 brains).

Uz [25] distinguished four different types: Type I has multiple branches on both sides, Type II has multiple branches arising from one side of the P1 segment and one or maximum two branches arising from the other segment, Type III has only one thick artery on each segment and Type IV has multiple branches on one segment and no branches on the other.

Rassi et al. [21] classified them into four types as well: Type I, when one stem originated from each P1 segment, Type II, when one stem originated from one P1 segment and supplied the other hemisphere as well, Type III, when two branches originated from each P1 segment and Type IV, when three or more branches originated form each P1 segment.

We used the classification suggested by Park et al. [16] and adapted data gathered from every study. As we can see in Table 4 branching patterns observed by authors varied vastly. Perforating arteries can arise as small branches or a large stem that divides later into a net of smaller perforators. According to Caruso et al. [2] almost 30% of P1 segments consisted of many small perforators of the same diameter.

CONCLUSIONS

Posterior thalamoperforating arteries are important terminal vessels supplying deep parts of the human brain as well as cranial nerves nuclei. Bonnaud and Sala-

Table 4. Branching pattern of posterior thalamoperforating arteries

Study	Type I	Type II	Type III	Type IV	Type V
Lang, 1978 [10]	20%	26%	42%	N/A	8%
Pedroza, 1986 [18]	7,1%	35.7%	28.6%	17.8%	10.70%
Rassi, 1992 [21]	46.66%	Not available	46.66%	Not available	6.66%
Uz, 2007 [25]	20%	33%	40%	7%	Not available
Park, 2010 [16]	38.50%	26.90%	19.20%	3.80%	11.50%

ma [1] pointed a great importance of those branches and their relation with vision problems. Occlusion of those arteries may cause many neurological symptoms connected with the oculomotor nerve. Because of their small diameter, TPAs are unable to be visualised in any available diagnostic test such as 1.5T or 3T magnetic resonance imaging, digital subtraction angiography or angio-computed tomography. It is possible to visualise those arteries using 7T magnetic resonance angiography but for now it is used only for research purposes. The closest artery to the basilar artery bifurcation is usually the main vessel in the thalamoperforating complex and it is usually very close to the bifurcation, therefore it can be easily damaged or closed. Moreover TPA can exist as a single stem supplying both hemispheres, known as "artery of Percheron". Occlusion of this artery can result in bilateral thalamic infarct. There were many branching patterns presented by different authors. In our opinion the most accurate branching pattern is the one presented by Park et al. [16]. In more than half of analysed studies, authors did not found presence of posterior TPAs. Anatomical knowledge of perforating arteries and their variations can ensure the safety of surgical procedures in this region.

REFERENCES

1. Bonnaud I, Salama J. [An ischemic syndrome of the oculomotor nucleus: associated clinical and anatomical variations on a theme]. Rev Neurol (Paris). 2003; 159(8-9): 781–785, indexed in Pubmed: 13679721.
2. Caruso G, Vincentelli F, Giudicelli G, et al. Perforating branches of the basilar bifurcation. J Neurosurg. 1990; 73(2): 259–265, doi: 10.3171/jns.1990.73.2.0259, indexed in Pubmed: 2366083.
3. Cosson A, Tatu L, Vuillier F, et al. Arterial vascularization of the human thalamus: extra-parenchymal arterial groups. Surg Radiol Anat. 2003; 25(5-6): 408–415, doi: 10.1007/s00276-003-0153-7, indexed in Pubmed: 14504815.
4. Duret M. Recherches anatomiques sur la circulation de l'encéphale. Arch Phys Norm Path. 1874; 1: 60–91.
5. Grand W, Hopkins LN. The microsurgical anatomy of the basilar artery bifurcation. Neurosurgery. 1977; 1(2): 128–131, indexed in Pubmed: 615962.
6. Hara K, Fuijino Y. The thalamoperforating arteries. Acta Radiol Diagn. 1966; 5: 192–200.
7. Heubner O. Zur topographie der Ernährungsgabiete der einzelnen 40 hirnarterien. Zbl Med Wiss. 1872; 52: 817–821.
8. Kaya AH, Dagcinar A, Ulu MO, et al. The perforating branches of the P1 segment of the posterior cerebral artery. J Clin Neurosci. 2010; 17(1): 80–84, doi: 10.1016/j.jocn.2009.03.046, indexed in Pubmed: 20006506.
9. Krayenbühl HA, Yasargil MG. Cerebral Angiography. 2nd ed. Philadelphia: J B, Lippincott 1968.
10. Lang J, Brunner FX. Über die rami centrales der aa. Cerebri anterior and media. Gegenbaurs Morph Jb. 1978; 124: 364.
11. Lazorthes G, Gouhze A, Salamon G. Vaseularization et Circulation Cerebrales. Masson, Paris 1976.
12. Lazorthes G, Salamon G. The arteries of the thalamus: an anatomical and radiological study. J Neurosurg. 1971; 34(1): 23–26, doi: 10.3171/jns.1971.34.1.0023, indexed in Pubmed: 5539644.
13. Marinković S, Gibo H, Milisavljević M. The surgical anatomy of the relationships between the perforating and the leptomeningeal arteries. Neurosurgery. 1996; 39(1): 72–83, indexed in Pubmed: 8805142.
14. Marinković S, Milisavljević M, Kovacević M. Interpeduncular perforating branches of the posterior cerebral artery. Microsurgical anatomy of their extracerebral and intracerebral segments. Surg Neurol. 1986; 26(4): 349–359, indexed in Pubmed: 3529466.
15. Pai BS, Varma RG, Kulkarni RN, et al. Microsurgical anatomy of the posterior circulation. Neurol India. 2007; 55(1): 31–41, indexed in Pubmed: 17272897.
16. Park SQ, Bae HG, Yoon SM, et al. Morphological characteristics of the thalamoperforating arteries. J Korean Neurosurg Soc. 2010; 47(1): 36–41, doi: 10.3340/jkns.2010.47.1.36, indexed in Pubmed: 20157376.
17. Párraga RG, Ribas GC, Andrade SE, et al. Microsurgical anatomy of the posterior cerebral artery in three-dimensional images. World Neurosurg. 2011; 75(2): 233–257, doi: 10.1016/j.wneu.2010.10.053, indexed in Pubmed: 21492726.
18. Pedroza A, Dujovny M, Ausman JI, et al. Microvascular anatomy of the interpeduncular fossa. J Neurosurg. 1986; 64(3): 484–493, doi: 10.3171/jns.1986.64.3.0484, indexed in Pubmed: 3950725.
19. Percheron G. Etude Anatnmique du Thalamus de l'Homme Adulte et de sa Vaseularisation ArterieUe. These de Medicine, Paris 1966.
20. Percheron G. Les artères du thalamus humain. II. Artères et territoires thalamiques paramédians de l'artère basilaire communicante. Rev Neurol. 1976; 132: 309–324.
21. Rassi NA, Antunes ÁCM, Braga FM. The posterior thalamoperforating artery (the main perforating trunk from P1). Microsurgical study. Jornal Brasileiro de Neurocirurgia, São Paulo, v.3, 1992: 103–107.
22. Rhoton Jr A. The Supratentorial Arteries. Neurosurgery. 2002; 51(suppl 4): S53–S120.
23. Saeki N, Rhoton AL. Microsurgical anatomy of the upper basilar artery and the posterior circle of Willis. J Neurosurg. 1977; 46(5): 563–578, doi: 10.3171/jns.1977.46.5.0563, indexed in Pubmed: 845644.
24. Salamon G. Atlas de la Vaseularisation Arterielle du Cerveau Chez I'Homme. Sandoz, Paris 1971.
25. Uz A. Variations in the origin of the thalamoperforating arteries. J Clin Neurosci. 2007; 14(2): 134–137, doi: 10.1016/j.jocn.2006.01.047, indexed in Pubmed: 17113294.
26. Westberg G. Arteries of the basal ganglia. Acta Radiol Diagn (Stockh). 1966; 5: 581–596, indexed in Pubmed: 5957860.
27. Zeal AA, Rhoton AL. Microsurgical anatomy of the posterior cerebral artery. J Neurosurg. 1978; 48(4): 534–559, doi: 10.3171/jns.1978.48.4.0534, indexed in Pubmed: 632878.