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Paper Accepted* **ISSN Online 2406-0895**

Original Article / Оригинални рад

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Microanatomical study of the posterior medial choroidal artery

Микроанатомска студија задње унутрашње хороидне артерије

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Received: February 9, 2022
Revised: November 7, 2022
Accepted: November 8, 2022
Online First: November 10, 2022
DOI: https://doi.org/10.2298/SARH220209109B

*__Accepted papers__ are articles in press that have gone through due peer review process and have been accepted for publication by the Editorial Board of the *Serbian Archives of Medicine*. They have not yet been copy-edited and/or formatted in the publication house style, and the text may be changed before the final publication.

Although accepted papers do not yet have all the accompanying bibliographic details available, they can already be cited using the year of online publication and the DOI, as follows: the author's last name and initial of the first name, article title, journal title, online first publication month and year, and the DOI; e.g.: Petrović P, Jovanović J. The title of the article. Srp Arh Celok Lek. Online First, February 2017.

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SUMMARY

Introduction/Objective The aim of this study was a detailed examination of microanatomy of the medial posterior choroidal artery (MPChA).

Methods The microanatomical characteristics of the MPChA were studied in 30 formalin fixed brain hemispheres using × 6.3 to × 10 magnification of the stereoscopic microscope. The arteries were injected with the mixture of 10% India ink and gelatin. The second group of 10 hemispheres consisted of specimens injected with methylmethacrylate fluid into the cerebral arterial vessels, for the preparation of corrosion casts.

Results The MPChA was present in all 30 hemispheres, always as the single artery. The MPChA were divided into proximal and distal types of vessels. We distinguished two segments of the MPChA: a cisternal and plexal. Proximal MPChA was present in 53.3% of cases, with the caliber of 0.6-1.0 mm (mean 0.8 mm). The point of its origin from the posterior cerebral artery was always before the origin of the first temporal cortical branch. Distal MPChA existed in 46.7% of cases, with the diameter of 0.4-1.0 (mean 0.74 mm). The cisternal segment the most frequently gave of the origin of fine branches to the cerebral crus, medial geniculate body and thalamus. The plexal segment gave rise arteries to the thalamus, and choroid branches for the supply of the choroid plexus of the third ventricle. Anastomoses in the region of the MPChA were found in all of 20 examined brains, most often among the plexal branches.

Conclusion The results describing the microanatomical characteristics of the MPChA may have diagnostic and microsurgical significance.

Keywords: medial posterior choroidal artery; choroid plexus; thalamus; cerebral crus

САЖЕТАК

Увод/Циљ Циљ ове студије био је детаљна анализа микроанатомских карактеристика унутрашње задње хороидне артерије (УЗХА).

Методе Микроанатомске карактеристике УЗХА су проучаване на 30 можданих хемисфера фиксираних формалином коришћењем стерео микроскопа са увеличањима од × 6.3 до × 10. Артерије су инициране мешавином 10% раствора туша и растопљеног желатина. Користили смо и другу групу од 10 хемисфера одраслих особа где смо у артерије иницирали течни метилметакрилат, да бисмо припремили корозионе препарате.

Резултати УЗХА је била присутна на свих 30 хемисфера, увек по једна артерија. Описали смо два типа ове артерије, проксимални и дистални. Свака УЗХА је такође подељена на цистернални и плексусни сегмент. Проксимални тип УЗХА је постојао на 53,3% хемисфера, са измереним пречником од 0,6-1,0 mm (просечно 0,8 мм). Одвајао се од стабла задње мождане артерије пре места одвајања прве кортикалне слепоочне гране. Дистални тип УЗХА је постојао на 46,7% хемисфера, са измереним пречником од 0,4-1,0 мм (просечно 0,74 мм). Цистернални сегмент је најчешће био део артерије који је давао неуралне гране за крус церебри, унутрашње коленасто тело и таламус. Плексусни сегмент је давао гране за таламус и хороидни сплет на крову треће мождане коморе. Анастомозе у сливу УЗХА су биле присутне на свим препаратима, најчешће између плексусних грана.

Закључак Добијени подаци о микроанатомским карактеристикама УЗХА могу имати дијагностички и микрохируршки значај.

Кључне речи: унутрашња задња хороидна артерија; хороидни сплет; таламус; можданикрак

INTRODUCTION

The morphology and topography of the medial posterior choroidal arteries (MPChA) is extremely complex and so little known. In most anatomical textbooks no mention is made of the MPChA. The MPChA, as a branch of the posterior cerebral artery (PCA), has been neglected in the anatomical, neuroradiological, and the neurosurgical literature [1, 2, 3].

Several microanatomical, microneurosurgical and angiographic studies described deep arteries of the brain and their importance, but choroidal arteries received very modest attention [4–7]. The choroidal arteries are positioned in the close relation with the pineal gland, and the posterior and medial surfaces of thalamus. Displacements of the choroidal arteries from the correct anatomical position are sign of pineal or thalamic tumors [8, 9]. The microsurgical procedures with use of sophisticated optical equipment are frequently performed for endovascular treatment of the cerebral arteriovenous malformations. Correct and detailed knowledge of the microanatomical characteristics of the choroidal arteries is essential for a safe and precise intervention [10, 11].

The aim of this microanatomical research investigating the choroidal arteries is to provide necessary anatomical support for enhancing diagnostic procedures, and the quality of microsurgical interventions in this region.

METHODS

For this microanatomical study of the medial posterior choroidal artery (MPChA) we used thirty human hemispheres (15 right and 15 left) with no pathological changes, from the collection of the Laboratory for Vascular Anatomy. The adult brains (18 males and 12 females), belonged to persons with an average age of 56.4 years (from 42–71 years). We perfused the cerebral arterial system with worm water mixed with a 4% formalin solution, and we finally intraarterially injected a 10% mixture of India ink and melted gelatin through the basilar artery. After the period of three weeks necessary for fixation, the brain specimens were meticulously dissected.

We used another ten hemispheres for preparing the corrosion casts, important for a precise analysis of topographical relationships between specific branches. The fluid of methylmethacrylate, with added hardener and color pigment, was injected into the basilar

artery. The process of hardening of methylmethacrylate was completed in four hours, and for the next 14 days the injected specimens were immersed in 40% solution of potassium hydroxide necessary for corrosion of the soft tissue. The hot water was used for the final cleaning of digested specimens. The corrosion cast specimens of cerebral arteries were analyzed under the zoom microscope (Leica MZ6), and photographed by a digital photo camera (Leica DFC295). We engaged the specific software (Leica Interactive Measurements) for realizing different kind of measurements. The obtained data were introduced into the schematic drawings of every specimen. The statistical analysis that we used were mean values with standard deviation (SD). The research method of using the corrosion casts in analyses provided a precise 3D spatial distinction between the arteries, offering much better specimens than traditional dissections. On the other side the length of time required for the preparation and examination in detail for every specimen is incomparable with any other method of research used in morphological studies. The study protocol was approved by the Ethics Committee of the Faculty of Medicine, University of Belgrade, Belgrade, Serbia (No. 1322/V-10, Date 20-05-2021).

RESULTS

The PCA gave off the MPChA in all 30 (100%) studied hemispheres, always one artery. According to the level of beginning from the posterior cerebral artery (PCA) we distinguished between an a) proximal MPChA (MPChAprox), and b) distal MPChA (MPChAdist). We described two segments of the MPChA: a cisternal and plexal segment. The cisternal segment extended from the point of origin of the artery to the choroid plexus of the third ventricle where the plexal segment began.

a) The MPChAprox, found in 16 (53.3%) cases, bilaterally present in three (20%) brains, began in the anterior peduncular mesencephalic region from the posterior side of the

PCA. It was characterized by the point of its beginning from the PCA before the origin of the first temporal cortical branch. The MPChAprox originated from the precommunicating (P1) segment of the PCA in 4 (25%) cases, and from the postcommunicating (P2) segment of the PCA in 12 (75%) hemispheres (Figure 1). In two (12.5%) cases the MPChAprox has had a common origin with the collicular artery form the PCA (Figure 2). The mean caliber of the MPChAprox at the level of its beginning was 0.8 ± 0.11 mm (from 0.6 to1.0 mm) (Table 1).

Curving around the mesencephalic crus the cisternal segment of the artery was in close relationship with the inferior side of its parent vessel, superior cerebellar artery, basal vein of Rosenthal and the trolchlear nerve in the ambient cistern. The MPChAprox coursed backwards following the lateral side of the mesencephalon, immediately bellow the medial geniculate body, and extended into the quadrigeminal (collicular) cistern (Figures 1, 2). After making a sharp bend it formed a loop and entered the choroid plexus of the third ventricle and continued by the plexal segment. This tortuous retrothalamic segment is in close proximity to the lateral surface of the pineal gland. It extended throughout the length of the choroid plexus of the third ventricle, adjacent to the internal cerebral vein and the opposite MPChA, to the anterior pole of the thalamus where the artery passed through the interventricular foramen and entered the choroid plexus of the lateral ventricle (Figures 3 and 4).

b) The MPChAdist, found in 14 (46.7%) cases, originated from the postcommunicating (P2) segment of the PCA in the region of the bifurcation or ramification of the PCA in temporal cortical branches, below or behind the pulvinar of the thalamus. Of the 14 MPChAdist, 11 (78.6%) originated directly from the PCA, 2 (14.3%) from the parietooccipital artery, and 1 (7.1%) from the calcarine artery (Figure 3). The average caliber of the MPChAdist at the level of its beginning was 0.74±0.17 mm (from 0.4 to 1.0 mm) (Table 1)

The MPChA coursed from the level of its subsplenial beginning inward, superiorly and anteriorly. In a lateral projection the artery run upward at an angle of 45 degree, with the

concave middle part in a form of number 3. The lower curved part belongs to the parapineal segment, and the upper part after the midpoint is the plexal segment of MPChA. Projection of the lateral posterior choroidal arteries (LPChA) is immediately caudally to the previous, and finally the most caudal vessel is splenial artery encircling the caudal and dorsal surfaces of the splenium of the corpus callosum (Figure 5).

The postero-medial choroidal system gives off various kinds of branches. Ventrally, the first group of cisternal braches are arteries for the supply of the cerebral crus. A second group is constituted with branches which supply the medial geniculate body. Another group is composed of arteries for the caudal part of pulvinar. Posteriorly, and superiorly, various plexal branches irrigated the superomedial part of the pulvinar, the superomedial part of the thalamus and the choroid plexus in the roof of the third ventricle.

DISCUSSION

Most frequently only one MPChA was noticed in our specimens. However, other authors described a range of 1–3 arteries (average 1.7) [4, 5, 12]. In this study, we noticed this artery to average 0.8 and 0.74 mm in diameter, for the MPChAprox and MPChAdist respectively, which is similar to 0.8 mm reported by Fujii et al. [4], and larger than the value of 0.4 mm described in the article by Garcia et al. [5]. The origin of the MPChAprox (75%) from the P2 segment of the PCA was the most frequent in the present study, in agreement with 85% reported by Fujii et al. [4], and not consistent with the findings (5.1%) of Garcia et al. [5]. In this series, proximal and distal type of the MPChA was described according to the different point of its origin, a characteristics described only by our group of authors. We did not noticed the presence of duplication of the MPChA reported only by Garcia et al. [5].

The MPChA supplies tumors, arteriovenous malformations (AVM), and aneurysms arising in and adjacent to the choroid plexus and the third ventricle [4].

Neoplastic masses in the pineal gland are uncommon and a rare clinical entity, with less than 10% of pediatric tumors, and less than 1% of all intracranial tumors. Patients with pineal tumor may present symptoms connected to elevated intracranial pressure, such as headache, nausea, vomiting, and somnolence [13]. The pineal gland is centrally positioned with a very complex relationships, below the splenium of corpus callosum, posterior the third ventricle, above and behind the mesencephalic tectum and medially to the left and right thalamus [4, 8]. Different microscopical, macroscopical and radiological appearances are characteristics of pineal tumors. The MPChA has a close relationship with lateral borders of the pineal gland, and local changes in its shape are visible in case of pineal neoplasm. The tumors originating in the pineal gland make a pressure and displace the MPChA superiorly and posteriorly. The further enlargement of the tumor makes additional displacement of the MPChA posteriorly. Meningeoma arising from the tentorium behind the pineal gland grow slowly, push and displace the MPChA anteriorly [4, 8, 9].

The MPChA territory infarctions are rare events with sparse data about the vascular teritories within the thalamus. Medial parts of the thalamus and the pulvinar, related to the roof of the third ventricule and mainly supplied by branches of the MPChA are the most frequently affected, but with no evident specific neurologic dysfunctions [14]. The MPChA territory infarcts may be lacunar, with a small ischemic area within the thalamus, and they can be asymptomatic and silent in long-term follow-up [15]. Another MPChA branches, originating more distally may supply the anterior thalamic nuclei, but disabilities are usually absent or slight. The anatomical explanation is existence of plexiform anastomotic supply from branches of the anterior choroidal artery, from the choroid plexus of the lateral ventricle, entering through the interventricular foramen [14]. The existence of the peduncular branches originating from the collicular, from the superior cerebellar artery, and form the PCA are the explanation

why the eye movement disorders and sensory-motor dysfunction were uncommon for the selective MPChA territory infarct [4, 16].

Arteriovenous malformation (AVM) of the brain is a congenital vascular disease, an anomaly characterized by direct connection between arteries, the nidus (the arteriovenous shunt) and draining veins, characterized by an internidal network of maldeveloped vessels [17]. An AVM perfused by the PCA is located near the posterior part of the corpus callosum and the deep cerebral veins to form a callosal circle. The feeding arteries may involve the MPChA and the treatment was mostly via this small artery. Surgical resection, radiotherapy, and endovascular treatment are available therapeutic methods for AVM [18]. Embolization with the microcatheter performed as a curative procedure through the MPChA should be taken with the main aim to secure the weak structures [18, 19].

Aneurysm of the MPChA is very rare reported condition. Because of the specific position the MPChA curving lateraly to the mesencephalon and entering the roof of the fourth ventricle, the rupture of the aneurysm of its cisternal segment is manifested as subarachnoid hemorrhage in the ambient cistern, and spasm affecting the PCA, comparing to the rupture of the aneurysm of its plexal segment causing the ventricular and thalamic hemorrhage. Because of the small size of the MPChA, preferable endovascular coiling with parent artery protection is unfeasible, and aneurisms or parent vessels are isolated and clipped by open surgery [20].

Numerous anastomoses interconecting the choroidal arteries, coming from the internal carotid artery and PCA, exist in the structure of choroid plexus. If the occlusion of the proximal part of the PCA happens, the part of PCA distally to the blockade receives blood in the opposite direction from capillary choroidal network of the lateral and third ventricles respectively, supplied by the anterior choroidal artery, branch of the internal carotid artery, then via the MPChA entering the PCA distally to the obstruction [1]. The existence of abnormal periventricular collaterals from the choroidal vessels is typically connected to

Moyamoya disease. The existence of enlarged pathological interconnections between the deep parts of the medullary and choroidal arteries results in reversed blood flow to the cortical area [21]. The occurrence of periventricular subependymal hemorrhage is a common manifestation of Moyamoya disease in adults. The enlarged choroidal collaterals are responsible for bleeding in the area of atrium of the lateral ventricle [22]. The MPChA may play an important role in supply of subependymal arteries involved in repeated hemorrhage in patients with Moyamoya disease. The potential trigger of recurrent hemorrhage is the existence of ventricular microaneurysms in the choroidal arteries [23]. Reduction of choroidal anastomoses, after the superficial temporal-middle cerebral artery bypass surgery, was confirmed in 85% of hemispheres [21].

CONCLUSION

The MPChA was the most common point of origin of neural arteries to the cerebral crus, medial geniculate body, thalamus and choroid plexus of the third ventricle. The data obtained on the microanatomical characteristics of the MPChA may have diagnostic and microsurgical implications.

ACKNOWLEDGEMENT

This work was supported by Grant No. 200110 (175061), by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

Conflict of interest: None declared.

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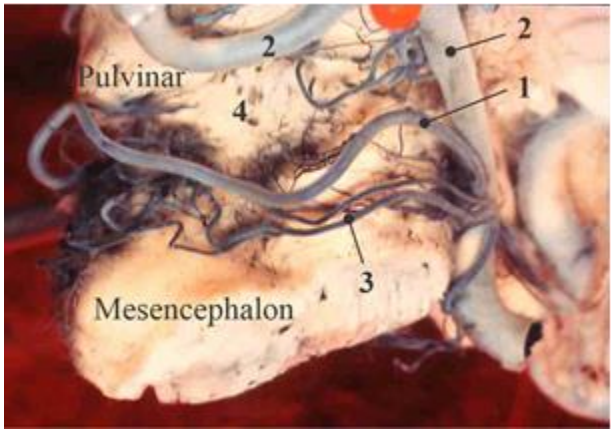

Figure 1. 1 – Long proximal medial posterior choroidal artery; 2 – originating from the prominent posterior cerebral artery; 3 – curving around the mesencephalic crus above the collicular artery; 4 – and below the medial geniculate body; (lateral view, dissection of specimen injected with India ink)

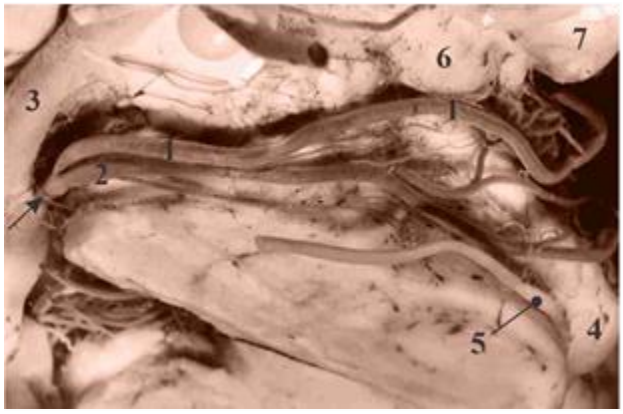

Figure 2. 1 – the MPChAprox with a common origin (arrow) with the 2 – collicular artery from the 3 – PCA; 4 – note the inferior colliculus; 5 – the trochlear nerve;6 – the medial geniculate body; 7– the pulvinar (lateral view, dissection of specimen injected with India ink)

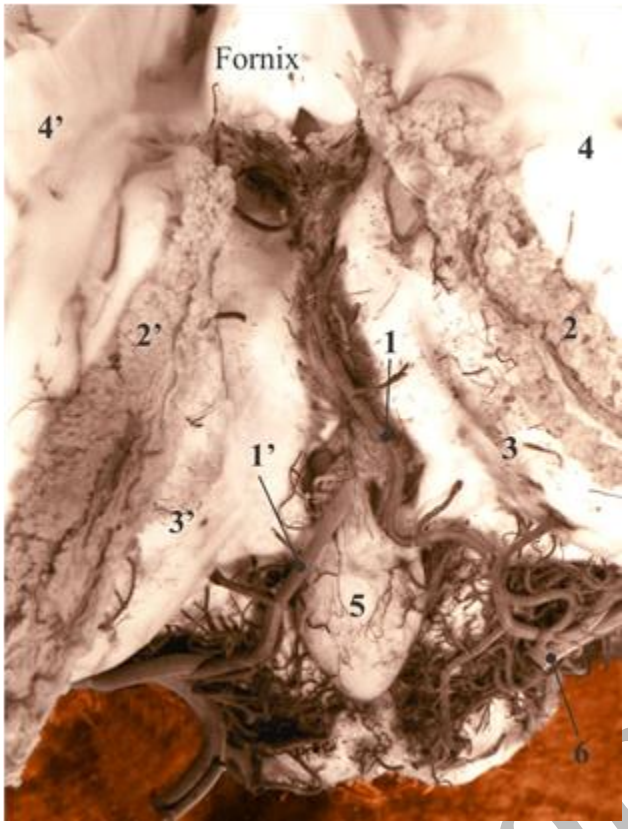

Figure 3. The roof of the third ventricle; plexal segments of the right MPChAprox (1) and the left MPChAdist (1') extending throughout the length of the roof; right and left choroid plexus (2, 2') of the lateral ventricle; right and left thalamus (3, 3'); right and left caudate nucleus (4, 4'); the pineal gland (5); right PCA (6) (dorsal view, dissection of specimen injected with India ink)

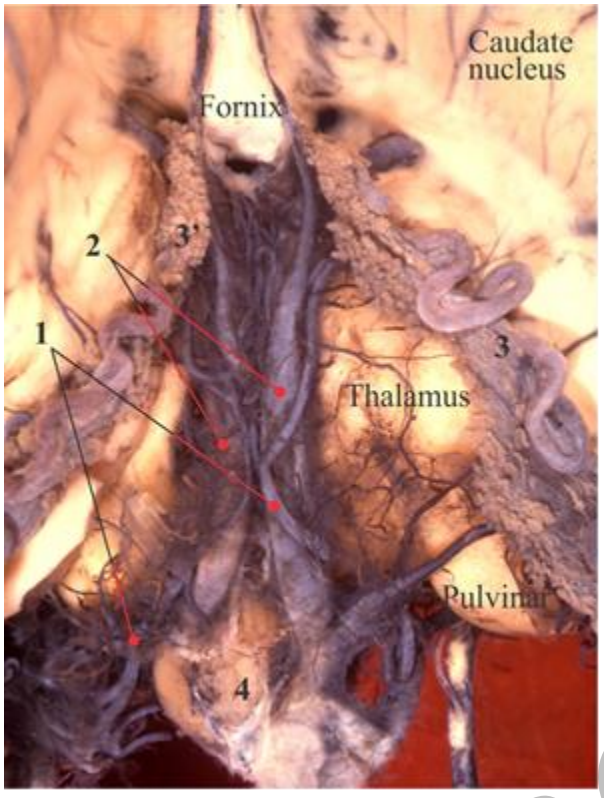

Figure 4. The roof of the third ventricle; plexal segments of the right and the left medial posterior choroidal artery (1) adjacent to the internal cerebral veins (2); right and left choroid plexus (3, 3') of the lateral ventricle; the pineal gland (4) (dorsal view, dissection of specimen injected with India ink)

Figure 5. Corrosion cast of the right PCA (1), medial view; the thalamoperforating arteries (2); right medial posterior choroidal artery (3); right lateral PChA (4); the splenial branch (5) of PCA over the dorsal side of splenium

Table 1. Morphometric characteristics of the medial posterior choroidal artery

Artery	Frequency (%)	Diameter (mm) Range (Mean±SD)
MPChAprox	16 (53.3%)	0.6–1 (0.8 ± 0.11)
MPChAdist	14 (46.7%)	0.4–1 (0.74 ± 0.17)

MPChAprox – proximal medial posterior choroidal artery; MPChAdist - distal medial posterior choroidal artery

