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Original Article
Animal Morphophysiology

Anatomic study of the arterial vascularization of the brain base of paca (*Cuniculus paca*)[1]

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ABSTRACT.- Sasahara T.H.C., Fontes V.F.N.P., Garcia D.O., Rocha D.W., Oliveira F.S., Leal L.M., Machado M.R.F. & Dias F.G.G. 2020. **Anatomic study of the arterial vascularization of the brain base of paca (*Cuniculus paca*)**. *Pesquisa Veterinária Brasileira 40(9):733-737*. Universidade de Franca, Avenida. Dr. Armando Salles Oliveira, 201, Parque Universitário, Franca, SP, 14404-600, Brazil. E-mail: fernandagosuen@yahoo.com.br

Paca (*Cuniculus paca* Linnaeus, 1766), rodent belong to the Cuniculidae family, has encouraged numerous scientific researches and for this reason could be an experimental model in both human and veterinary areas. And recently, the economic exploitation of the meat cuts, has being direct implication in its zootechnical importance. However, no anatomical descriptions regarding the vascularization of the base of the brain in this rodent has being found. Thus, the aim of the present study was to describe the arteries and the pattern of the vasculature and to compare it with the other species already established in the literature. For this, five pacas, donated by the Unesp Jaboticabal Wildlife Sector, were euthanized followed by the vascular arterial system was injected with red-stained-centrifuged latex by the common carotid artery. After craniectomy, the brains were removed and the arteries were identified and, in addition, compared with those described in other animal species. The presence of the right and left vertebral arteries, close to the medulla oblongata, was detected, originating the basilar artery, which divided into the terminal branches of the right and left basilar artery. Ventral to the optic tract there was the right internal carotid artery and the left, dividing the middle cerebral artery and left rostral and right; dorsal to the optic chiasm, the medial branch of the rostral cerebral arteries was identified. Based on the results, it is concluded that the vascularization of the paca brain base is supplied by the carotid and vertebrobasilar system.

INDEX TERMS: Anatomy, arterial vascularization, brain base, paca, *Cuniculus paca*, anatomy, brain, arterial circuity, rodent, central nervous system, morphology.

RESUMO.- [Estudo anatômico da vascularização arterial da base do encéfalo da paca (*Cuniculus paca*).] A paca (*Cuniculus paca* Linnaeus 1766), roedor da família Cuniculidae, tem encorajado inúmeras pesquisas científicas, tornando-a modelo experimental tanto na área humana quanto na veterinária, além da recente exploração econômica de seus cortes cárneos, que favoreceu diretamente sua importância zootécnica. No entanto, não há até o momento, descrições anatômicas referentes à padronização da vascularização da base do encéfalo neste roedor. Assim, o objetivo do presente trabalho foi realizar tal delineamento arterial nessa região do sistema nervoso central e compará-lo com as demais espécies já estabelecidas na literatura. Para isso, foram eutanasiadas cinco pacas doadas pelo setor de Animais Silvestres da Unesp Jaboticabal, as quais foram submetidas posteriormente à injeção de látex centrifugado e corante líquido xadrez vermelho, pela artéria carótida comum. Após craniectomia e segregação do encéfalo de todos os cadáveres, realizou-se a identificação das artérias presentes na base deste órgão e, ademais, comparação destas com as descritas cientificamente em outras espécies

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animais. Detectou-se a presença das artérias vertebral direita e esquerda, próximas à medula oblonga, originando a artéria basilar, que se dividiu nos ramos terminais da artéria basilar direito e esquerdo. Ventral ao trato óptico verificou-se a artéria carótida interna direita e esquerda dividindo-se na artéria cerebral média e rostral direita e esquerda; ainda, dorsal ao quiasma óptico, identificou-se o ramo medial das artérias cerebrais rostrais. Com base nos resultados obtidos, conclui-se que a vascularização da base do encéfalo da paca é suprida pelo sistema carotídeo e vertebro-basilar.

TERMOS DE INDEXAÇÃO: Anatomia, vascularização arterial, base do encéfalo, paca, *Cuniculus paca* anatomia, cérebro, circuito arterioso, roedor, sistema nervoso central, morfologia.

INTRODUCTION

Rodents belong to the order Rodentia, represented by the largest number of mammals of the Brazilian fauna, including paca (*Cuniculus paca* Linnaeus, 1766), which is found both in Brazilian territory and in Latin America (Dubost & Henry 2006).

Due to the diversity of rodent species, several studies have investigated the vascularization of the base of the brain (Reckziegel et al. 2001, Aydin et al. 2005, 2008, Araújo & Campos 2005, Azambuja 2007, Aydin 2008, Silva et al. 2016, Costa et al. 2017a); so far, there are no descriptions of this pattern in paca. Thus, the aim of this study was to describe the arterial vascularization of the brain base in this large rodent and to compare it with the other animal species, aiming at morphological standardization, especially the origin and arterial distribution, since the wild animal anatomy is essential to the clinic and surgery practices veterinary, futures researches and for conservation programs.

MATERIALS AND METHODS

The work was approved by the Animal Ethical Use Committee of the "Faculdade de Ciências Agrárias e Veterinárias" (FCAV), "Universidade Estadual Paulista" (Unesp), Jaboticabal Campus (017754/13) and by the "Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis" (IBAMA-SISBIO - 38942-1).

Five adult pacas, three males and two females, approximately 10kg, were donated by the Unesp Jaboticabal Wildlife Sector, breeding facility of specimens of the Brazilian fauna for scientific purposes (registration number 482508).

The animals were euthanized by previous sedation with 3mg/kg of meperidine hydrochloride (Cristália®, Itapira/SP) associated with 1mg/kg of midazolam (Medley®, Campinas/SP), both intramuscularly, in a single application. The animals were then anesthetized with 25mg/kg ketamine hydrochloride (Vetnil®, Louveira/SP) and 0.5mg/kg xylazine hydrochloride (Konig, Mairinque/SP) intramuscularly, in a single dose. Additionally, 19.1% intracardiac potassium chloride injection (HalexIstar Pharmaceutical Industry, Goiânia/GO), dose-effect, was performed until cardiopulmonary arrest.

Then, the left common carotid artery of all pacas was cannulated for injection of 60% centrifuged latex (Colitex, Colina/SP) pigmented with red liquid dye (Sherwin-Williams, Ribeirão Preto/SP) until filling the arterial system.

Subsequently, the bodies were frozen at -20°C for one week for complete latex polymerization and then thawed and fixed in 10% paraformoldehyde (Neon Comercial Ltda, São Paulo/SP) by intramuscular injections. The preservation was made in 30% saline solution (Eurofarma Laboratório S.A., Ribeirão Preto/SP).

Craniectomy was carefully performed by the oscillating saw (Dremel® - Racine, Wisconsin, United States) to remove the brain, avoiding damage to its vascular structures, as the meninges are closely associated with the skull. After isolation of the organ, we proceeded to identify the arteries present at the base of the brain and compare them with those already described in the literature for other animal species. The anatomical terms were based on the Nomina Anatomica Veterinaria (2017).

RESULTS

All animals in the study had the same arterial arrangement. No difference was observed when comparing males and females pacas. The arteries and branches of the base of the brain were illustrated in Figure 1 and the comparisons with the other rodents species shown in Table 1.

It was observed that the right and left vertebral artery (1), present at the level of the medulla oblongata, is anastomosed to origin the basilar artery (2), which extends over the entire length of the brainstem as a unique vessel, with rectilinear path and considerable diameter, irrigating the medulla oblongata, trapezoid body, pons and cerebellum.

In the midbrain, the basilar artery bifurcated symmetrically in terminal branches of the right and left basilar artery (3), with paths close to the mammillary body and hypophysis.

At the level of infundibulum and ventral to the optic tract, the right and left internal carotid arteries (4) were

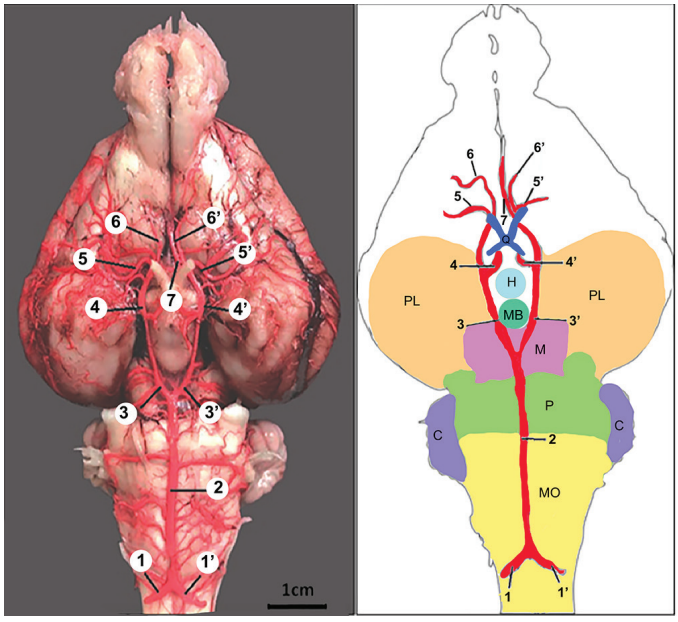

Fig.1. Photographic image (left side) and schematic (right side) of the base of the paca (*Cuniculus paca*) brain, demonstrating its arterial vascularization. Vertebral arteries right (1) and left (1'), basilar artery (2), branches of the basilar artery right (3) and left (3'), internal carotid arteries right (4) and left (4'), middle cerebral arteries right (5) and left (5'), rostral cerebral arteries right (6) and left (6'), medial branches of the rostral cerebral arteries (7), medulla oblongata (MO), cerebellum (C), pons (P), mesecephalon (M), piriform lobe (PL), mamillary body (MB), hypophysis (H), optic chiasm (Q).

Table 1. Comparasion of the arterial vascularization of the paca with the others rodents species

Animals	Arteries							
	Vertebral	Basilar	Terminal branches of the basilar artery	Internal carotid	Middle cerebral	Rostral cerebral	Medial branche of the rostral cerebral artery	Reference
Capybara (*Hydrochoerus hydrochaeris*)	x	x	x	-	x	x	x	Reckziegel & Lindemann 2001
Chincilla (*Chinchilla lanígera)*	x	x	x	x	x	x	x	Araújo & Campos 2005
Porcupine (*Hystrix cristata)*	x	x	x	-	x	x	x	Aydin et al. 2005
Paca (*Cuniculus paca)*	x	x	x	x	x	x	x	Dubost & Henry 2006
Agouti (*Dasyprocta aguti*)	x	x	x	x	x	x	x	Dubost & Henry 2006
Nutria (*Myocastor coypus)*	x	x	x	-	x	x	x	Azambuja, 2007
Red Squirrel (*Sciurus vulgaris)*	x	x	x	x/-	x	x	x	Aydin, 2008
Ground Squirrel (*Spermophilus citellus)*	x	x	x	-	x	x	x	Aydin et al. 2008
Rabbit (*Oryctolagus cuniculus*)	x	x	x	x	x	x	x	Souza & Campos 2013
Galea (*Galea spixii)*	x	x	x	x	x	x	x	Costa et al. 2017b
Gerbil (*Meriones unguiculatus)*	x	x	x	x	x	x	x	Costa et al. 2017a

identified, which, after a short course, were divided into the right and left middle cerebral arteries (5) and the right and left rostral cerebral arteries (6); the latter presenting small caliber, located between the optic nerve and piriform lobe. Dorsal to the optic chiasm, the medial branch of the rostral cerebral arteries was identified (7).

In this context, it was noted that paca presents the closed cerebral arterial circuit, as a pentagonal shape and basically vascularized by the right and left internal carotid arteries and vertebrobasilar system, being classified as type II, as established by De Vriese (1905).

DISCUSSION

The brain's arterial circuit (which surrounds mammillary body, the tuber cinereum, the hypophysis and the optic chiasm) (Ferreira & Prada 2005) is important for the vascularization of the main organ of the central nervous system, which is responsible for receiving and processing information of the whole organism (Lima et al. 2013). Thus, the identification and the pattern of the arterial structures are essential not only for taxonomy and phylogeny, but also to the care and clinical neurological surgical treatment (Kieltyka-Kurc et al. 2015).

Different morphologies in brain vascularization among animal species can be attributed to evolutionary adaptations related especially to behavioral and dietary aspects. Reckziegel et al. (2001) reported that the largest differences related to the types of brain vascularization in mammals were found in rodents and that, regardless of the type of vascularization, the vessels that carry blood to this region of the nervous system are small in diameter.

Comparisons of the arteries and branches of the brain base of pacas with the other rodents species, as well as the types of the base brain vascularization according to the classification of De Vriese (1905) are shown in Table 1 and Table 2, respectively.

In the present study, it was observed that paca presents the vertebral artery at the base of the brain in accordance with Bugge (1970) in muroiods, Bugge (1971a) in rats, bamboo rats, mices and jerboas, Bugge (1971c) in mole-rat, Alcântara & Prada (1996) in dogs, Reckziegel et al. (2001) in capybaras, Araújo & Campos (2005) in chinchillas, Aydin et al. (2005) in guinea pigs, Bugge (1971b) and Aydin (2008) in red squirrel, Aydin et al. (2009) in ground squirrels, Barreiro et al. (2012) in coatis, Lima et al. (2013) in anteater (*Tamandua tetradactyla*), Souza & Campos (2013) in rabbits, Silva et al. (2016) in agouti, Costa et al. (2017a) in gerbils and Costa et al. (2017b) in preá (*Cavia aperea*).

Similar to described in cutias by Silva et al. (2016), the vertebral artery in pacas has larger caliber when compared to other vessels. Vertebral arteries are branches of the

Table 2. Type of vascularization of the brain base of different rodents, according to De Vriese's classification* (1905)

Carotid and vertebrobasilar system	Vertebral-basilar system
Paca	Chincilla
Agouti	Galea
Capybara	Nutria
Gerbil	Porcupine
	Red Squirrel

* De Vriese (1905).

subclavian arteries (Araújo & Campos 2005, Lima et al. 2013) and close to the intervertebral foramina, emit the muscular and spinal branches, which unite and enter the spinal canal to form the ventral spinal artery (Alcântara & Prada 1996, Reckziegel et al. 2001).

In this sense, the basilar artery, which is the direct continuation of the ventral spinal artery (Alcântara & Prada 1996, Silva et al. 2016), was identified in the pacas as well as in other species listed in Table 1. In contrast, the terminal branches of the basilar artery (caudal cerebellar artery, middle cerebellar and rostral cerebellar) were not mentioned in coatis (Barreiro et al. 2012). These branches originate the right and left pituitary arteries (Araújo & Campos 2005). Lima et al. (2013) reported that the anteater's middle cerebral artery arose from the internal carotid artery in contrast to that in the agouti (Silva et al. 2016). In a systematic analysis of the arteries at the base of the capybara's brain, Reckziegel et al. (2001) observed the lack of the rostral cerebral artery in 6.7% of cases on the right and in 3.3% of cases on the left and Araújo and & Campos (2005) reported that the rostral cerebral artery was lacking in 3.3% of cases in the chinchilla on the right and left; the author also remarked that a thin vestigial vessel might be found where the rostral cerebral artery originated.

Still regarding the basilar artery, the rectilinear course of this vessel was noted in the five pacas, disagreeing with Alcântara & Prada (1996) when reporting the winding course in 70% of the dogs evaluated by them. The authors related this evident tortuosity to the phase of the arterial vascularization model proposed by De Vriese (1905) in this species, characterized by the union of the carotid and vertebro-basilar systems, with opposite flows, and with the angulation established by the collateral branches of this artery. The sinuous path of the basilar artery has also been described by Lima et al. (2006) in cats. In addition, Souza & Campos (2013) described that in rabbits, the basilar artery may originate solely from the left or right vertebral artery.

The intracranial segment of the internal carotid artery as well as its rostral and caudal branches were found in paca, similarly in castor (Frąckowiak & Śmiełowski 1998), dogs (Alcântara & Prada 1996), chinchillas (Araújo & Campos 2005), swine (Ferreira & Prada 2005), yaks (Ding et al. 2007), coatis (Barreiro et al. 2012), anteater (Lima et al. 2013), rabbits (Souza & Campos 2013), hares (Brudnicki et al. 2015), deer (Kieltyka-Kurc et al. 2015), agouti (Silva et al. 2016), gerbil (Costa et al. 2017a) and caves (Costa et al. 2017b). In contrast, it has not been described in guinea pigs (Aydin et al. 2005), adult capybaras (Reckziegel et al. 2001, Steele et al. 2006), nutria (Azambuja 2007) and ground squirrels (Aydin et al. 2009). In red squirrels, the intracranial segment of the internal carotid artery wasn´t found in four animals of the ten evaluated by Aydin (2008).

Reckziegel et al. (2001) and Steele et al. (2006) described in adult capybara the presence of fibrous cords in the common carotid arteries, where the origin of the extracranial segment internal carotid artery would normally be located, indicates that carotid brain irrigation existed during the embryonic phase and that the vertebrobasilar system invaded gradually the site, with consequent internal carotid atrophy. They also pointed out that partial or total atrophy of the extracranial segment of the internal carotid artery is present in other rodents, probably due to the strong jaw and adapted to the temporomandibular joint modified with rostro-caudal movements and well-developed musculature. In these animals, the vertebral system invades this area to compensate for the reduction in brain irrigation.

The middle cerebral artery was identified in the pacas, as well as in the other species in Table 1, providing collateral branches reaching the rostral choroid artery and the piriform lobe (Alcântara & Prada 1996, Ding et al. 2007). As well as in cutias (Silva et al. 2016), the middle cerebral artery it reaches the dorsal surface and distributes itself tree-wise; however, these authors cited the origin of the right and left middle cerebral arteries from the communicating rostral branch of the cerebral carotid at the level of the optic tract.

A rostral cerebral artery, also called the anterior cerebral artery (Alcântara & Prada 1996), associated with its middle branches, running medially through the dorsal region of the optic chiasm, reaching a longitudinal fissure, similar to Ding et al. (2007) in yaks. Unlike the current research in pacas, the rostral cerebral artery in the nutrias originates from the terminal branches of the basilar artery, according to Azambuja (2007). Araújo & Campos (2005) and Silva et al. (2016) reported that the rostral cerebral artery may be absent in chinchillas and agoutis, respectively.

Regarding the pattern of the arteries that supply the base of the paca brain, it can be classified as type II, according to De Vriese (1905), because it is performed equally by the carotid and vertebrobasilar system (responsibles for brain irrigation of the rostral and caudal regions, respectively) (Silva et al. 2016, Costa et al. 2017a, 2017b). Thus, as described in gerbils by Costa et al. (2017a), these systems emit vessels that are distributed in the regions of spinal cord, medulla oblongata, trapezoid body, pons, cerebral peduncle, cerebellum, piriform lobe, mamillary body, optic chiasm, optic nerve olfactory trigone and olfactory bulb. On the other hand, Reckziegel et al. (2001), Araújo and& Campos (2005), Aydin et al. (2005) and Azambuja (2007) described that in capybara, chinchilla, porcupine and nutria, respectively, cerebral vascularization depends solely or almost exclusively on the vertebrobasilar system (type III brain vascularization).

CONCLUSION

The vascularization of the base of the paca brain is performed by the carotid and vertebrobasilar system, similar pattern found in most rodents. It is believed that the absence of vascular anatomical variations in this region, observed among individuals of the same species and distinct gender, can be attributed to the reduced number of specimens analyzed in the present research.

Conflict of interest statement.- The authors declare no conflict of interest.

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