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Gross Anatomy and Vascularization of the Brain of Pacarana (*Dinomys branickii*)

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ABSTRACT

Background**:** The pacarana lives in South America and has herbivorous and nocturnal habits. It is a rare species with scarce data concerning its morphology and adding more data is important in establishing its vulnerability. The aim was to describe its macroscopic brain anatomy, as well as the brain vascularization.

Materials, Methods & Results**:** Two specimens were available for this study, that were donated *post-mortem*. The animals were injected with latex and fixed with 10% formaldehyde. Upon exposure and removal of the brain its main features were described. The rhinal fissure is single and the lateral sulcus arises from its caudal part. There are two sagittal sulci, an extensive medial sulcus and a short lateral sulcus. The piriform lobe is vermiform and the rostral part is smaller. The caudal colliculus is larger than the rostral colliculus and they are separated by a sulcus. The cerebellum has oval shape and the flocculus lobe is not conspicuous. The cerebral arterial circle was analyzed and described. The brain is supplied by the vertebrobasilar system only. The cerebral arterial circle is formed by the terminal branch of the basilar artery, the caudal communicating artery, the rostral cerebral artery and the rostral communicating artery. The caudal and middle cerebellar arteries are branches of the basilar artery. The terminal branch of the basilar artery originates the rostral cerebellar artery and the caudal cerebral artery. From the end of the caudal communicating artery and the beginning of the rostral cerebral artery arises the middle cerebral artery.

Discussion**:** The cerebral structures related to sensory inputs reflect the species usage of senses, or rather one is intrinsically correlated to the other. The caudal colliculus is larger than the rostral colliculus, as the former is related to hearing and the latter to the vision, this indicates that the visual sense is not so important. Indeed, the animals are nocturnal and have small eyes. The hearing on the other hand is used in social interactions, to indicate combat, threat and defensive situations, for example. The rhinencephalon has the most conspicuous external sensory structures and the animals use olfaction for social behaviors, even producing a gland exudate to mark territory. Most brain features are similar with other species in the infraorder Caviomorpha. The brain of the pacarana resembles the brains of the Patagonian mara, capybara and guinea pig. The common porcupine presents a different shape to the brain. The guinea pig and the common porcupine are lissencephalic. The animals that present sulci in the brain, follow this order from more to less girencephalic: capybara, mara and pacarana. The rhinal fissure is important because it delimits the rhinencephalon and it is present in all the animals mentioned above. In the mara, the colliculi are exposed in dorsal and lateral views, however, this does not happen for the pacarana. The cerebellum is similar in these species, but the flocculus is more pronounced in the guinea pig. The brain of Caviomorpha species is supplied only by the vertebrobasilar system in most species analyzed, as in the capybara, guinea pig, coypus, mara, chinchilla, degu and in pacarana, where the absence of the carotid artery was observed. In some species the rostral cerebral artery anastomosis in a single branch that runs towards the corpus callosum (degu, capybara, chinchilla and coypus), but in the pacarana the rostral cerebral artery is present in both left and right sides, then branching towards the corpus callosum and the splenial sulcus. In summary, the pacarana presents brain features similar to other Caviomorpha, with some specific species variation.

Keywords: morphology, mammal, Caviomorpha, rodent, artery.

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INTRODUCTION

A great amount of new species is discovered and described every year. Mora [11] estimated that 86% of terrestrial species on Earth have not been described yet. Despite this huge diversity many animals become extinct in an increasing rate [14] and from these very few have detailed information available about their habits and behavior, and less yet about their physiology and morphology.

The rodent pacarana (*Dinomys branickii*, Peters, 1873) is a rare animal, data concerning this species is scarce and additional data is necessary to better understand its vulnerability and extinction risk [17].

The pacarana inhabits forest environments in Colombia, Ecuador, Peru, Brazil and Bolivia [7,9,21]. It is the only living member of the family Dinomyidae [9] and the animals are nocturnal, herbivorous [7,8], and live in burrows placed under rocks [20], being also capable of climbing trees and walking on irregular grounds [13].

It can reach a weight of 15 kg and its gestation period lasts between 223-252 days [7,9], breeding once a year and having one or two offspring, a factor that contributes with their rarity [7].

Anatomical data are so far sporadic in the literature, and thus the aim of this study is to report the brain general features and the vascularization. The study of the brain is related to the habits and behaviors of the animals. Understanding its anatomy may be helpful specially when compared with ecology studies. The results were also compared with available information of Caviomorpha rodents.

MATERIALS AND METHODS

Animals

Two *post-mortem* pacaranas were received from Jaguar Conservation Fund, which criteria are supported by Normative Instruction no 154/2007 - IBAMA and current legislation (no 11.794/2008 that regulates animal research in Brazil) and collection authorized under the Authorization System and Biodiversity Information (Sistema de Autorização e Informação em Biodiversidade - SISBIO, no 54134-1). The specimens were stored in a freezer.

Anatomical technique

The animals were thawed and dissected. First, a ventral incision was made and the heart exposed. With the aid of a cannula and needle the animals were injected with formaldehyde 10% to fix, followed with latex injection to highlight blood vessels. The tegument in the head was removed and a small window was opened in the skull to aid fixation. Then the animals were immersed in formaldehyde 10%. A week later the skull was completely removed and the brain exposed.

Analyzes

The brain external macroscopic morphology was analyzed and the structures described. The arteries that supply the brain were evidenced by the latex and described. A camera Canon (Rebel T6) was used to photograph the material.

RESULTS

The pacarana has a girencephalic brain, though it does not present many sulci. It is worth emphasizing that due to the rarity of this species, only two specimens were available to this study and because of freezing, the brain was not in its best shape. The outline and general pattern of the brain is preserved, but further analyzes were not possible.

It presents a single rhinal fissure that arises near the medial border of the brain, on the caudal surface, it runs obliquely in a ventral direction until it reaches the lateral aspect of the brain, then it runs through it, forming a wave pattern until it reaches the olfactory bulb. The caudal part is deeper than the rostral part (Figure 1B).

In a dorsal view there are two sagittal sulci. The medial sagittal sulcus is extensive and the lateral sagittal sulcus is short, being located more rostrally than the former. Neither reaches any border of the brain (Figure 1A). Laterally, the lateral sulcus arises vertically from the caudal part of the rhinal fissure, itis deep and it curves backwards, forming a half-moon pattern (Figure 1B). Slightly caudal to the lateral sulcus is a very short sulcus, almost a depression, called ectolateral sulcus.

The caudal surface of the brain presents two vertical and slightly oblique sulci, the medial one being shorter, named them caudolateral sulcus and caudomedial sulcus by its topography. The rhinal fissure arises near the caudolateral sulcus. The medial aspect of the brain was not well preserved, but it is possible to identify a long splenial sulcus that runs for about two thirds of the hemisphere.

The piriform lobe is divided from the neopallium by the rhinal fissure, having vermiform shape. The limit with the olfactory tubercle is not very clear, but the rostral part of the piriform lobe is more caudal and smaller than the olfactory tubercle, which presents an elongated oval shape. Its caudal part is rounded and it can be separated from the cerebral peduncles located medial to it (Figures 1B & 2A).

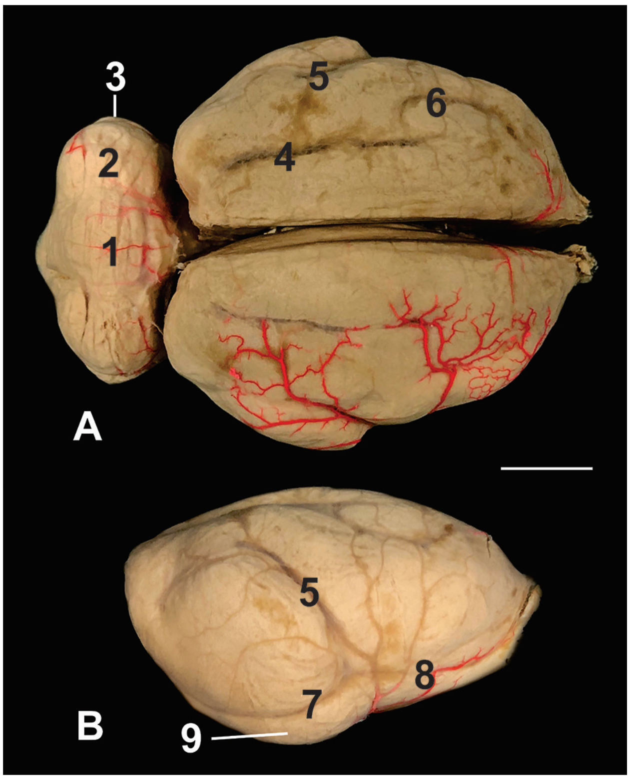

Figure 1. Brain of the pacarana. A- Dorsal view. B- Lateral view. 1- Vermis, 2- central lobe, 3- floccules lobe, 4- medial sagittal sulcus, 5- lateral sulcus, 6- lateral sagittal sulcus, 7- caudal part of the rhinal fissure, 8- rostral part of the rhinal fissure, 9- piriform lobe. [Bar= 1 cm].

Due to the state of the brain, the only noticeable features about the brain stem is that the cerebral peduncles, pons and medulla oblongata, are wide. The colliculi were in better shape. The caudal colliculus is larger both dorsally and laterally and it is separated from the rostral colliculus by a sulcus.

The cerebellum has an oval shape. The vermis is conspicuous in the midline, it is larger on the dorsal aspect of the cerebellum (Figure 1A). It presents three lobes, the central lobe is the largest one, its limit with the frontal lobe, the primary fissure, was in rostral aspect of the cerebellum (Figure 1A). The lateral one, called flocculus lobe is small and separated from the central lobe by the floccular fissure, where the rostral cerebellar artery lies (Figure 1A). It is possible to distinguish two parts in it, a more rounded dorsal part, the paraflocculus, and a thin ventral one, the flocculus, they are separated by a depression, the arcuate fissure. The caudal lobe is small, but it was too damaged to allow a better description.

Superficial arteries cover the surface of the brain. Some of the vessels leave impressions in their location and other vessels pass over sulci, such as the lateral sulcus. In the ventral aspect of the brain, the cerebral arterial circle is highlighted. It is formed by the terminal branch of the basilar artery, the caudal communicating artery, the rostral cerebral artery and the rostral communicating artery. The following description has a caudo-rostral direction.

The basilar artery presents two ramifications, the caudal and middle cerebellar arteries. Then it bifurcates forming two terminal branches. The terminal branch of the basilar artery originates four arteries, the rostral cerebellar artery, two mesencephalic arteries and the caudal cerebral artery. The caudal communicating artery has three thin ramifications, the rostral choroid artery, the piriform lobe artery and the hypophysial artery, which is the only one running medially. Then the middle cerebral artery arises following a latero-dorsal direction. The circle continues as the rostral cerebral artery, which communicates closing the circle. The internal ethmoidal artery arises from the rostral cerebral artery (Figure 2A).

The middle cerebral artery originates the lateral olfactory bulb artery and then branches into four arteries, the ventrolateral branch, the dorsocaudal branch, the terminal branch and the rostral branch. The ventrolateral branch bifurcates into ventral and lateral branches. The dorsocaudal branch ramificates further into caudal and dorsal branches, the latter bifurcates in two branches. All the cerebral arteries originate cortical branches, which may anastomose with one another (Figure 2C).

The rostral cerebral artery enters the medial aspect of the brain. It branches into three arteries, the pericallosal artery, that follows the trajectory of the corpus callosum, the splenial artery, which lays on the splenial sulcus and medial olfactory bulb artery. A rostral branch of the rostral cerebral artery passes over the border of the hemisphere and enters the dorsal surface, where it anastomosis with the branches of the middle cerebral artery. In the left hemisphere the pericallosal and splenial arteries arises from a bifurcation of the rostral cerebral artery (Figure 2B).

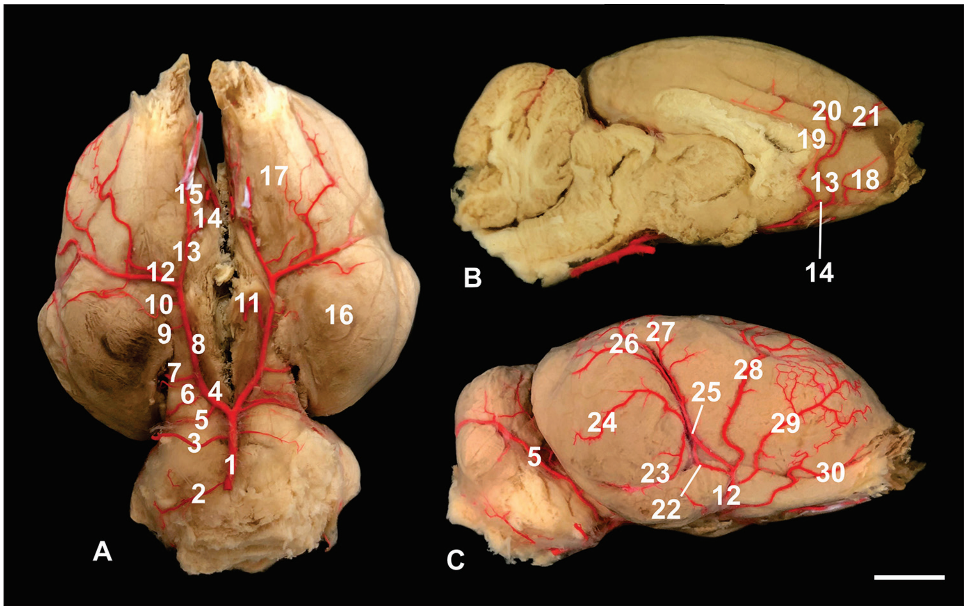

Figure 2. Arteries irrigating the brain of the pacarana. A- Ventral view. B- Medial view of the right hemisphere. C- Lateral view. 1- Basilar artery, 2- caudal cerebellar artery, 3- middle cerebellar artery, 4- terminal branch of the basilar artery, 5- rostral cerebellar artery, 6- mesencephalic arteries, 7- caudal cerebral artery, 8- caudal communicating artery, 9- rostral choroid artery, 10- piriform lobe artery, 11- hypophysial artery, 12- middle cerebral artery, 13- rostral cerebral arte, 14- rostral communicating artery, 15- internal ethmoidal artery, 16- piriform lobe, 17- olfactory tubercle, 18- medial olfactory bulb artery, 19- pericallosal artery, 20- splenial artery, 21- rostral branch of the rostral cerebral artery, 22- ventrolateral branch, 23- ventral branch, 24- lateral branch, 25- dorsocaudal branch, 26- caudal branches, 27- dorsal branch, 28- terminal branch, 29- rostral branch, 30- lateral olfactory bulb artery. [Bar= 1 cm].

DISCUSSION

Pacarana has small eyes, possibly indication poor visual acuity, inspite of Collins & Eisenberg [7] had a specimen which had cataracts but the animal orientation in the environment did not seem affected. The animals produce an exudate by glands in mucous membranes of the orbits, used by the males to mark territory and the author suggests this could be a useful visual mark on dark surfaces. The rostral colliculus is smaller than the caudal colliculus, which is another indication of this species poor visual sense.

The gland exudate is probably related to olfactory signals as specimen were often seen sniffing the locations marked with it. Naso-nasal, naso-anal and naso-genital contacts is a social behavior that was often noted and it is also related to olfaction, which can lead to sexual interactions or fighting [7]. The olfactory structures such as the piriform lobe, olfactory bulb and olfactory tubercle are conspicuous, complementing the data about olfaction.

They produce seven clearly defined sound types, which were observed in female-male encounters, related to thwarting, combat, threat and defensive situations, and to juveniles notify adults of its presence [7]. This suggests hearing is an important feature for this species, which explains the large caudal colliculi found in the species.

There are few descriptions of the brains of rodents in the literature, data from pictures were analyzed, but the brain is either not described or have a broad description. The brain of the pacarana presents similar morphology to that of the Patagonian mara (*Dolichotis patagonica*), capybaras (*Hydrochoerus hydrochaeris*) and guinea pigs (*Cavia porcellus*) as it can be observed in the pictures of Beddard [3] and Campos & Welker [6]. The brain of the common porcupine (*Erethizon dorsatum*) presents a different shape, being more quadrangular [10,19].

Considering these 5 animals, the capybara presents more sulci, followed by the mara and then the pacarana. The guinea pig and the common porcupine both present a lissencephalic neopallium, but the size of the brain of the former is smaller [3,6,10,19].

The medial sagittal fissure, called longitudinal fissure by Beddard [3], is more extensive in the mara and in the capybara, and those species present more short sulci in the neopallium than the pacarana, but they remain unnamed. One of these sulci is possibly the same as the pacarana lateral sagittal sulcus, which is also short. The common porcupine presents a rudimentary sagittal sulcus [3,6,10,19].

The topography and path of the rhinal fissure is also similar in all the animals, but in the capybara and the mara the fissure appears to be more ventral limiting a smaller rhinencephalon [3,6,10,19]. Apparently the rhinal fissure and the lateral sulcus are present in the guinea pig [10,19]. The lateral sulcus is more caudal in the pacarana than in the mara and it was not possible for us to distinguish it clearly in the picture of the brain of the capybara [3,6].

The colliculi are exposed in dorsal and lateral views in the mara [3], but this was not observed in the pacarana. The shape of the cerebellum is similar in these animals, but thecerebellum of the mara present a larger vermis and the flocculus is more conspicuous. In the guinea pig the flocculus is more protruding than in the other species [3,6,10,19].

The features of the cerebral arterial circle remain the same among the Caviomorpha, the few differences are described below. The main supply system for this infraorder is the vertebrobasilar system. The internal carotid artery was absent in the pacarana and in the following species it was either absent or reduced: the capybara, guinea pig, coypus (*Myocastor coypu*), mara, chinchilla (*Chinchilla lanigera*) and degu (*Octodon degus*) [1,2,4,5,12,16] The prehensile-tailed porcupine (*Coendou prehensilis*) is supplied by both vertebrobasilar and carotid system [5]. There is conflicting information concerning the agouti (*Dasyprocta aguti*): Bugge [5] reports only the vertebrobasilar system, but Silva *et al*. [18] reports both carotid and vertebrobasilar systems.

As individual variations, the specimen may present double arteries, not present a certain artery or have different origins for the same artery. In the capybara there is a rostral tectal artery, which can be doubled and may emerge from either the caudal cerebral artery or the terminal branch of the basilar artery [15]. In the degu the tectal artery is a branch of the caudal cerebellar artery [4]. In the single specimen of pacarana, two mesencephalic arteries arising from the terminal basilar artery was observed.

In the degu, capybara, chinchilla and coypus, the rostral cerebral artery anastomoses and forms a single artery which is directed to the corpus callosum, (the authors call this vessel inter-hemispheric artery in chinchilla and coypus) [1,2,4,15]. Whereas in the pacarana both rostral cerebral arteries form a corpus callosum artery, as well as a splenial artery which was formed by a bifurcation (in the right hemisphere) or branching at different points (left hemisphere) of the rostral cerebral artery.

Araújo [1] and Azambuja [2] analyzed the persistence of arteries in chinchilla and coypus, respectively, and reported than some animals presented double caudal cerebellar and caudal cerebral arteries. In coypus most animals presented the middle cerebellar artery arising from the caudal cerebellar artery. The rostral cerebellar artery was absent in some specimens of chinchilla. Reckziegel *et al*. [16] reported that more than half capybara specimen presented double cerebellar arteries and few presented double middle cerebral arteries. The guinea pig has two caudal cerebral arteries [12] and for the degu and the agouti, the middle cerebellar artery was not found [4,18]. Such features could not be analyzed in pacarana due to its rarity, but some variation is expected to occur among different species.

CONCLUSIONS

To conclude, the brain of the pacarana follows the same pattern than other Caviomorpha, with some species-specific variations. It presents less sulci than other girencephalic species, the capybara and the Patagonian mara. The cerebral arterial circle presents the usual arteries, but it is only irrigated by the vertebrobasilar system, being the internal carotid artery absent.

***Ethical approval*.** Two pacaranas were received post-mortem from Jaguar Conservation Fund, under the Authorization System and Biodiversity Information (Sistema de Autorização e Informação em Biodiversidade - SISBIO, no 54134-1) for collection, whose criteria are supported by Normative Instruction no 154/2007 - IBAMA and current legislation (no 11.794/2008 that regulates animal research in Brazil).

***Declaration of interest*.** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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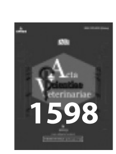

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