

Morphological Configuration and Topography of the Brain Arterial Supply of the One-humped Camel (*Camelus dromedarius*, Linnaeus 1758)

Configuración Morfológica y Topografía del Suministro Arterial del Encéfalo del Camello de una Joroba (*Camelus dromedarius*, Linnaeus 1758)

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SUMMARY: This study investigated the anatomy of the arteries of the brain, including the arterial circle of the brain, its branches and junctions, in five camel (*Camelus dromedarius*, Linnaeus 1758) following intravascular injection of colored latex via common carotid artery. The course and distribution of the arterial supply to the brain was described and morphological analysis was made. The basilar artery contributed to the blood supply of the brain in the camel in contrast to the situation in other Artiodactyla order.

KEY WORDS: Anatomy; Blood vessels; Camelidae; Circulatory system; Cerebral arterial circle.

INTRODUCTION

Nearly 400 years ago, Thomas Willis gave the most detailed anatomic description of the arterial anastomosis at the base of the brain, surrounded by cerebrospinal fluid. The arterial anastomotic ring that connects the internal carotid arteries, and vertebrobasilar circulation by communicating arteries is called circle arteriosus cerebri. In humans and black bears, blood supply to the brain is provided by two internal carotid arteries and two vertebral arteries (Akgun *et al.*, 2013). By internal carotid arteries, basilar artery and ethmoidal artery in horses (Budras *et al.*, 2003) and donkey (Ozgel *et al.*, 2007). In ruminant, the internal carotid artery is often absent and when it exists, it is vestigial (King, 1987). The maxillary artery contributes significantly to the cerebral arterial circle through the rete epidural mirabile while the basilar artery attached to the cerebral arterial circle where its blood flow directed caudally rather than rostrally (Kietyka-Kurc *et al.*, 2015; Alsafy *et al.*, 2017). In the giraffe, the vascular system was similar to the system described in ruminant, however the basilar artery was thin and could not participate in blood supply for the brain (Frackowiak *et al.*, 2008). In camel and in contrast to the situation in other ruminants, brain receives its blood supply from two sources: the proximal segment of the internal carotid arteries, which is formed from the rostral epidural rete mirabile and the basilar and cerebrospinal arteries which are considerable size, indicating the flow of blood towards

the cerebral arterial circle (circle of Willis) (Kanan, 1970; Smuts & Bezuidenhout, 1987; Ocal *et al.*, 1999).

The most detailed description of circulus arteriosus cerebri was published by Kanan, but this work don't showed photographs and topography by sections of these vessels in relation to the different parts of the head and encephalon. Recently, other description was published by Kie?tyka-Kurc *et al.* (2014). In recently published papers, we studied the rete mirabile epidural rostral and the venous sinuses in the dromedary camel (Jerbi *et al.*, 2016).

This aim of this study is to describe with sections and photographs the arterial pattern of the cerebral arterial circle, its branches, its anastomoses and the manner that it supply the brain of the one-humped camel, which will provide valuable information for both anatomists and physiologists.

MATERIAL Y METHOD

Animal material. Ethics statement. This study involved the use of five camel heads (camel body weights, age and sexes were not considered). The specimens were slaughtered

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and handled in accordance with the local ethical board guidelines of École Nationale de Médecine Vétérinaire Sidi Thabet of Tunisia. Each head was isolated immediately after slaughter by a section between the second and third cervical vertebrae.

Latex injection procedure. A first group of three heads was used to perform plan-by-plan classical progressive dissections and transverse and dorsal sections, that allowed the extraction of the encephalon within its connections to cerebral arteries. The head and the cranial extremity of the neck were injected with a 10 % formalin solution via cannulas placed in the right and left common carotid arteries and external jugular veins. Fixation takes 12 to 24 hours, and then, demineralized water was introduced through the same cannulas to wash the formalin salts. For all of these 5 heads, between 60 and 100 ml of very diluted and red-colored latex neoprene was injected immediately after rinsing with demineralized water in both common carotid arteries. The injection of latex was conducted progressively with hand pressure, using 60 ml syringes, until the coloration of the little arterioles in the conjunctiva was visible.

In order to identify the topography and the relationships of the arteries on the base of the brain in the camelids, a second group composed of two heads, with no previous injection for conservation was used. Indeed, in combination with injection of red latex into the artery, the external jugular veins were carefully dissected and cannulated followed by manual injection of a very-diluted solution of blue colored latex neoprene. Cannulas were systematically placed in a way to bypass the venous valves system of the external jugular vein, commonly located next to the first cervical vertebrae, in order to achieve a satisfactory filling. Near 400 ml of latex neoprene were used for each head, and the injection was systematically stopped at the appearance of resistance. Heads were then maintained at +4 °C during 24 hours, until the solidification of the injected latex was suitable. In these two heads, sections on one and sagittal sections on the other were performed. These were carried with a JS600 bandsaw. Pictures were taken with a Nikon digital camera. The anatomical nomenclature used was adopted from the established terminology of the *Nomina Anatomica Veterinaria* (International Committee on Veterinary Gross Anatomical Nomenclature, 2017).

RESULTS AND DISCUSSION

The brain of the camel received its arterial blood supply from the basilar artery and the intracranial part of internal carotid artery, also known as cerebral carotid artery

(Ocal *et al.*), which was represented by the rostral epidural rete mirabile (Fig. 1).

The basilar artery (A. basilaris). It was formed by the junction of the two vertebral arteries at the ventral aspect of the medulla oblongata. It passes in a rostral direction ventral to the medulla oblongata and the sulcus basilaris of the pons. It fused rostrally with both caudal communicating arteries in the median plane and gave off arteries supplying the pons, labyrinthine artery and caudal and rostral cerebellar arteries (Fig. 2).

The caudal cerebellar arteries (Aa. cerebelli caudalis). The caudal cerebellar arteries encircle the ventrolateral aspect of the medulla oblongata to reach its dorsal aspect where they ramify in the caudal part of the cerebellum. They are originated from the basilar artery, perpendicular to its long axis (Fig. 3).

The rostral cerebellar arteries (Aa. cerebelli rostralis). A variable number of vessels, involving two, three or even four blood vessels, represented them. Corresponding branches stemmed not only from the caudal communicating artery (most frequently two or three in number), but also from the rostral part of the basilar artery (usually represented by a double blood vessel). They supplied the corpora quadrigemina, the rostral and dorsal aspect of the cerebellar hemispheres as well as the vermis, and finally anastomosed with the caudal cerebellar arteries (Fig. 3).

The internal auditory arteries (Aa. auditiva interna). The internal auditory arteries supplied the vestibular apparatus and cochle, it was an end artery. From its origin, it curved around the caudal margin of the pons, detached branches to the caudal aspect of the cerebellum. The artery anastomosed with the most rostral twig of the caudal cerebellar arteries (Fig. 3).

Pontine arteries (Aa. pontis). These comprised 2 o 4 branches which arise from each side of the basilar artery. They run almost parallel to one other and supply the ventrolateral aspect of the pons. They anastomosed with the rostral cerebellar arteries and the internal auditory artery (Fig. 3).

The internal carotid arteries, the intracranial part (Aa. carotis interna). Very brief, the internal carotid arteries, in their terminal segments, were in intracranial position. They are also called cerebral carotid artery. They emerges from the rostral epidural rete mirabile and represented the major parental blood vessel in the cerebral arterial circle (Fig. 3). The terminal segment of each internal carotid artery gave off the caudal communicating artery, the rostral cerebral artery, the middle cerebral artery, and the rostral choroidal artery.

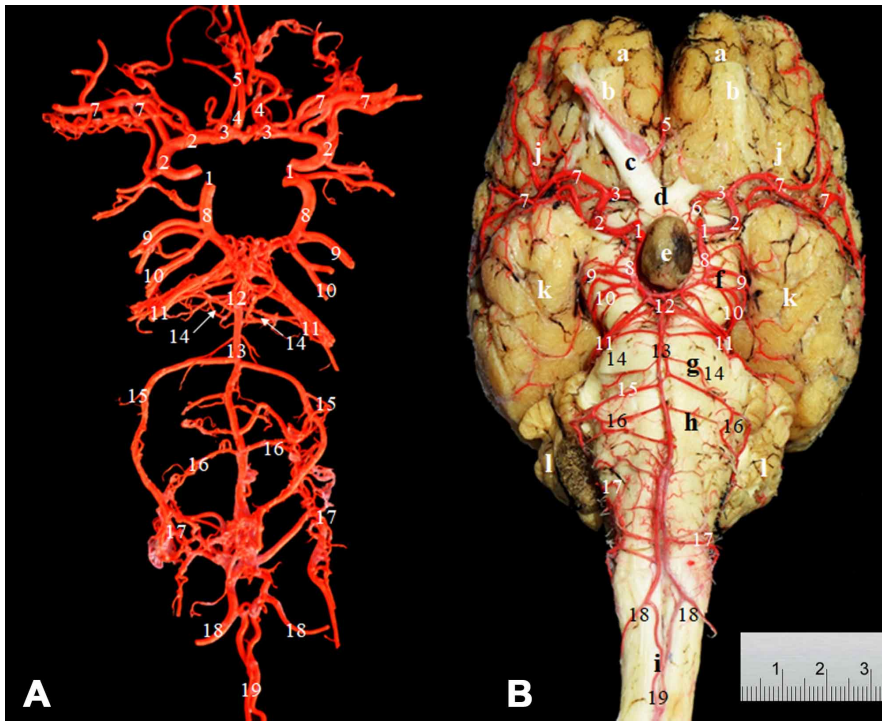


Fig. 1. Dorsal (A) and ventral (B) view of the cerebral arterial circle and its connections and branches of the one-humped camel (*Camelus dromedarius*). a- Frontal lobe. b- Olfactory tract. c- Optic nerve. d- Optic chiasm. e- Hypophysis pituitary. f- Cerebral peduncles. g- Pons. h- Medulla oblongata. i- Spinal cord. j- Piriform lobe (rostral). k- Piriform lobe (caudal). l- Cerebellum. 1- Intracranial part of internal carotid artery (Rostral connection with the rostral epidural rete mirabile). 2- Rostral cerebral artery. 3- Rostral communicating artery. 4- Callosal artery. 5- Marginal artery. 6- Peri-infundibular plexus. 7- Middle cerebral artery. 8- Caudal communicating artery. 9- Caudal cerebral artery (anterolateral artery). 10- Caudal cerebral artery (poterolateral artery). 11- Rostral cerebellar artery. 12- Accessory posterior communicating artery. 13- Basilar artery. 14- Pontine artery. 15- Internal auditory artery. 16- Caudal cerebellar artery. 17- Medulla oblongata artery. 18- Rostral spinal artery. 19- Ventral spinal artery.

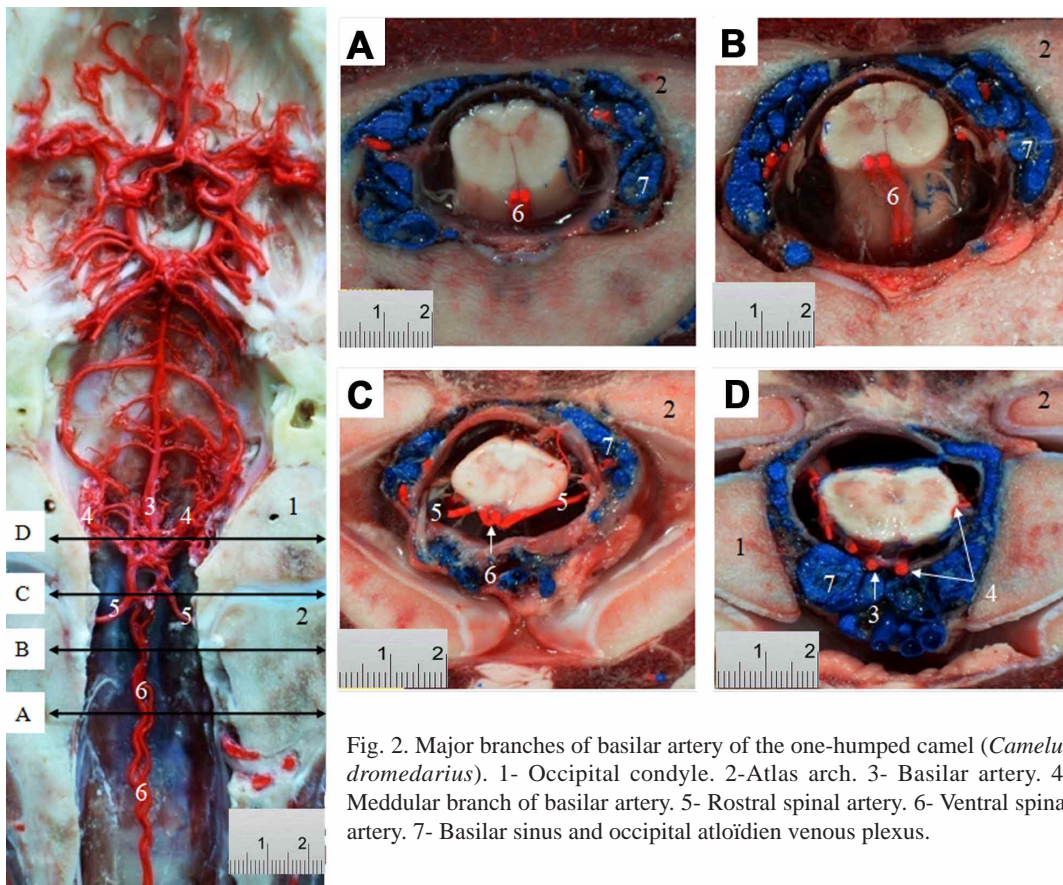


Fig. 2. Major branches of basilar artery of the one-humped camel (*Camelus dromedarius*). 1- Occipital condyle. 2- Atlas arch. 3- Basilar artery. 4- Medullary branch of basilar artery. 5- Rostral spinal artery. 6- Ventral spinal artery. 7- Basilar sinus and occipital atloidien venous plexus.

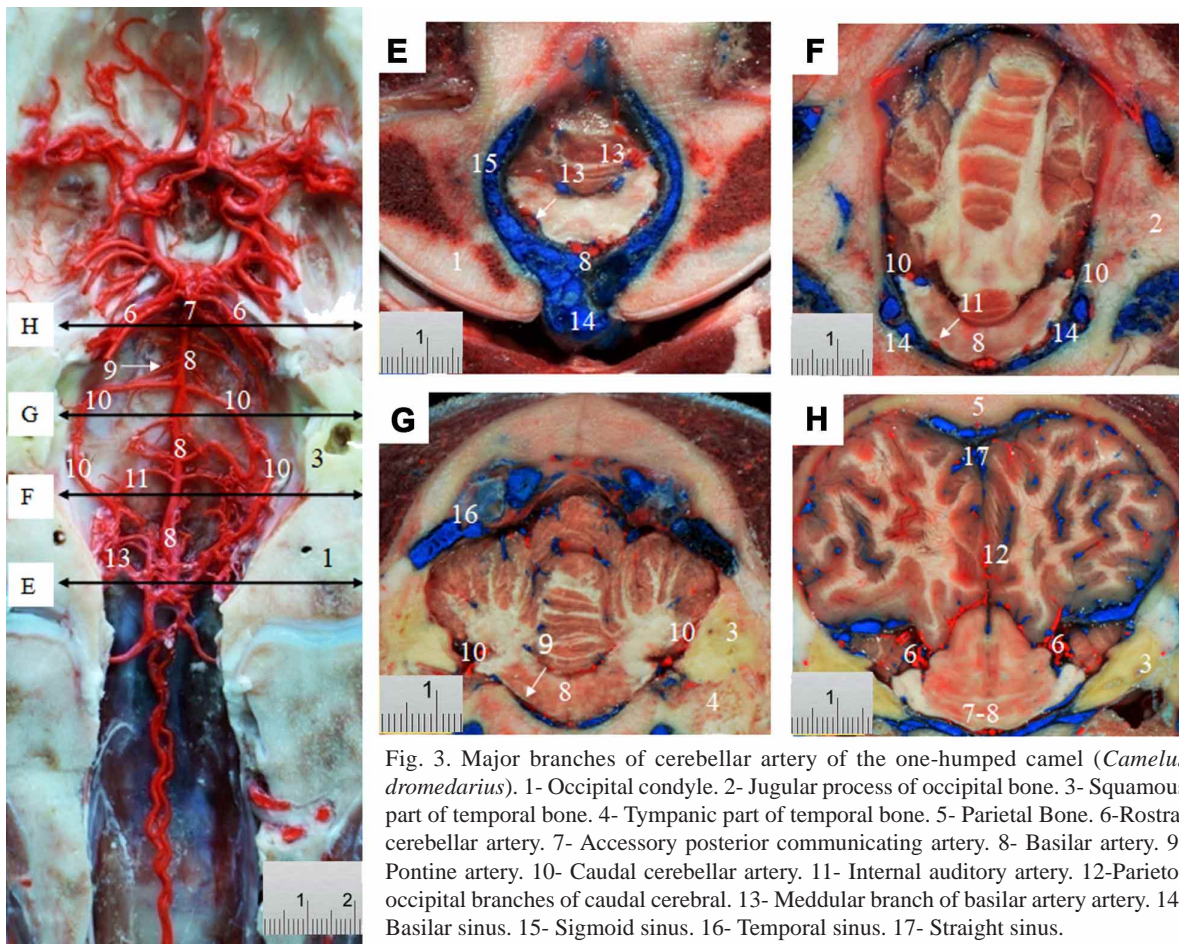


Fig. 3. Major branches of cerebellar artery of the one-humped camel (*Camelus dromedarius*). 1- Occipital condyle. 2- Jugular process of occipital bone. 3- Squamous part of temporal bone. 4- Tympanic part of temporal bone. 5- Parietal Bone. 6-Rostral cerebellar artery. 7- Accessory posterior communicating artery. 8- Basilar artery. 9- Pontine artery. 10- Caudal cerebellar artery. 11- Internal auditory artery. 12-Parieto-occipital branches of caudal cerebral. 13- Meddular branch of basilar artery. 14- Basilar sinus. 15- Sigmoid sinus. 16- Temporal sinus. 17- Straight sinus.

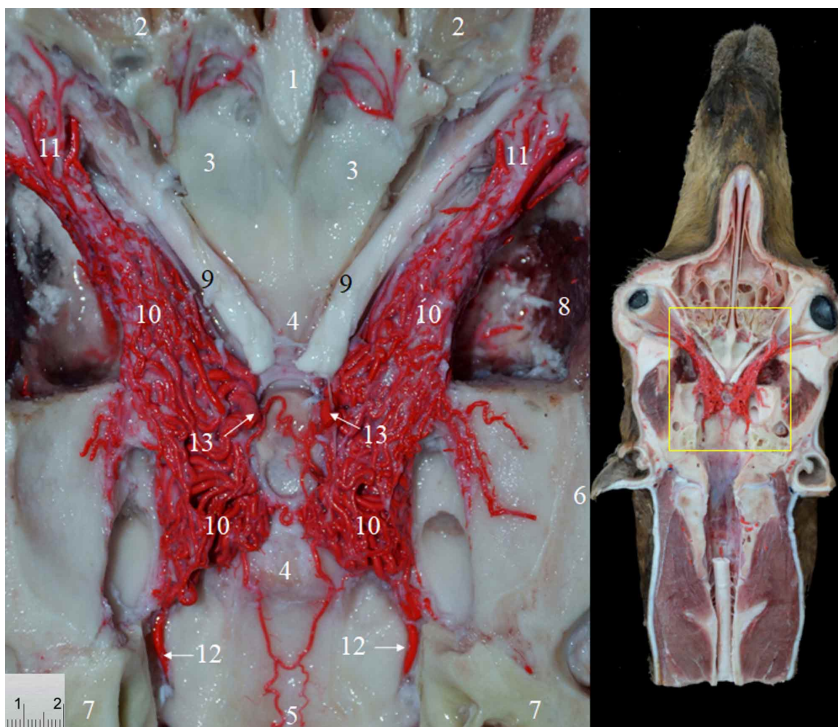


Fig. 4. Dorsal section of one-humped camel head (*Camelus dromedarius*). 1- Vomer. 2- Ethmoid bone. 3- Sphenoidal sinus. 4- Basisphenoid bone. 5- Basioccipital bone. 6- Parietal Bone. 7- Squamous part of temporal bone. 8- The temporal muscle. 9- Optic nerve. 10- Rostral epidural rete mirabile. 11- Ophthalmic rete mirabile. 12- Internal carotid arteries, extracranial part. 13- Internal carotid arteries, intracranial part.

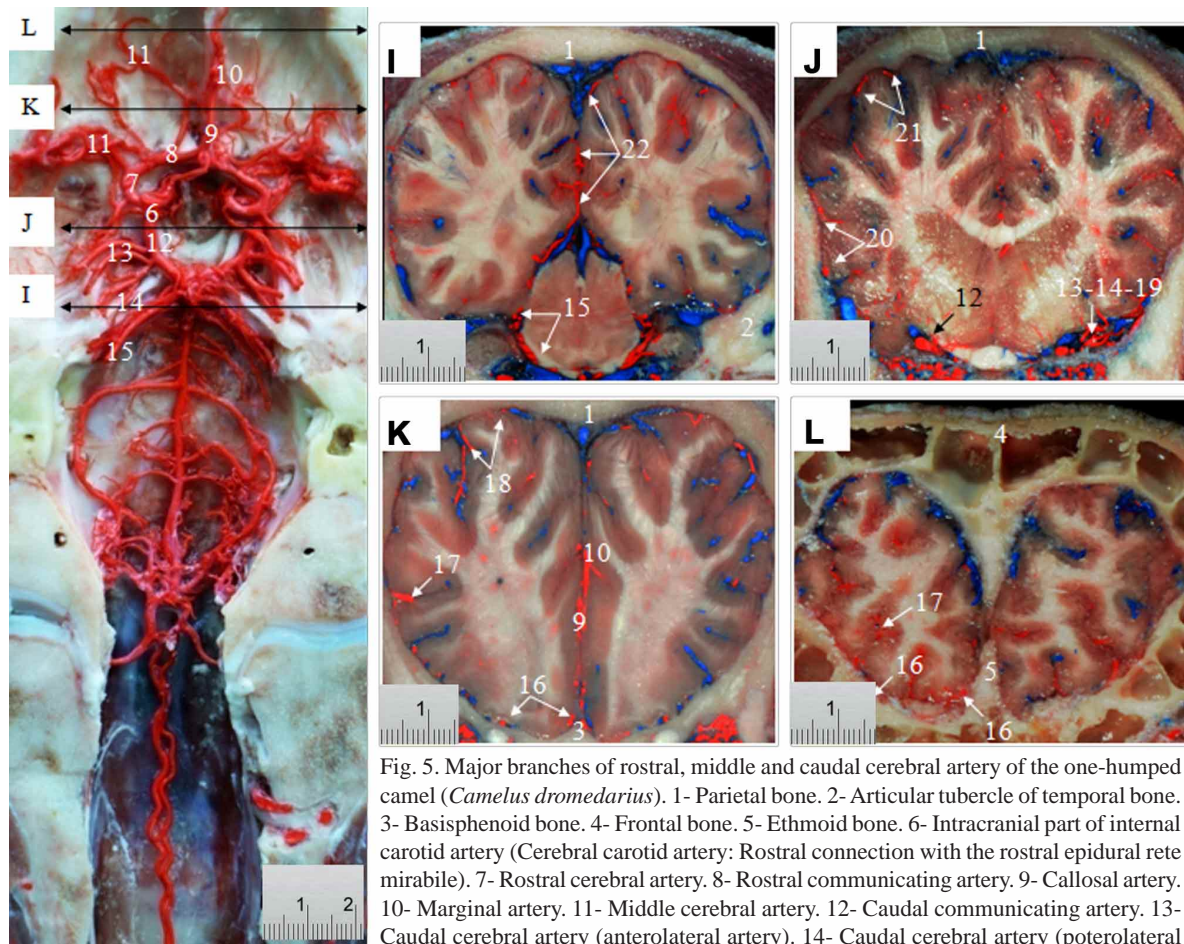


Fig. 5. Major branches of rostral, middle and caudal cerebral artery of the one-humped camel (*Camelus dromedarius*). 1- Parietal bone. 2- Articular tubercle of temporal bone. 3- Basisphenoid bone. 4- Frontal bone. 5- Ethmoid bone. 6- Intracranial part of internal carotid artery (Cerebral carotid artery: Rostral connection with the rostral epidural rete mirabile). 7- Rostral cerebral artery. 8- Rostral communicating artery. 9- Callosal artery. 10- Marginal artery. 11- Middle cerebral artery. 12- Caudal communicating artery. 13- Caudal cerebral artery (anterolateral artery). 14- Caudal cerebral artery (posterolateral artery). 15- Rostral cerebellar artery. 16- Ethmoidal artery. 17- Rostral branches of rostral cerebral artery. 18- Parietal branches of middle cerebral artery. 19- Lenticulostriate arteries. 20- Inferior division of middle cerebral artery. 21- Superior division of middle cerebral artery. 22- Parieto-occipital branches of caudal cerebral artery.

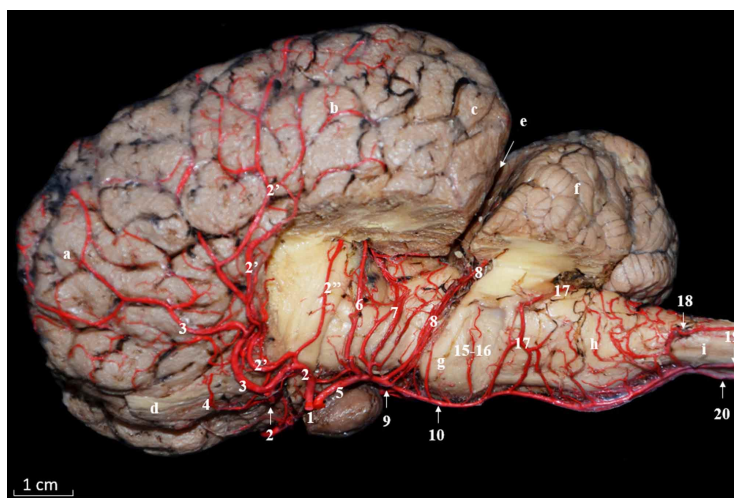


Fig. 6. Lateral view of the left side of brain of one-humped camel head (*Camelus dromedarius*) after removal of the dura mater, piriform lobe and ventral part part of the cerebellum showing arterial irrigation. a- Frontal lobe of brain. b- Parietal lobe of brain. c- Occipital lobe of brain. d- Olfactory tract. e- Transverse fissure. f- Cerebellum. g- Pons. h- Medulla oblongata. i- Spinal cord. 1- Intracranial part of internal carotid artery (Rostral connection with the rostral epidural rete mirabile). 2- Rostral cerebral artery. 2'- Cortical branch of the rostral cerebral artery. 2''- Central branch of the rostral cerebral artery. 3- Middle cerebral artery. 4- Marginal artery. 5- Caudal communicating artery. 6- Caudal cerebral artery (anterolateral artery). 7- Caudal cerebral artery (posterolateral artery). 8- Rostral cerebellar artery. 9- Accessory posterior communicating artery. 10- Basilar artery. 15- Pontine artery. 16- Internal auditory artery. 17- Caudal cerebellar artery. 18- Medulla oblongata artery (Medullary branches). 19- Rostral spinal artery. 20- Ventral spinal artery.

The caudal communicating arteries (Aa. communicans caudalis). The two caudal communicating arteries run caudally toward the cerebral peduncles and formed the caudal part of the cerebral arterial circle. They resembled in shape the U letter, organized around the hypophysis (Figs. 1-6). They connected the intracranial part of the internal carotid arteries with the basilar artery. They gave off the caudal cerebral artery (anterolateral and posterolateral arteries) and a variable number of branches of the rostral cerebellar artery.

The rostral cerebral arteries (Aa. Cerebelli rostralis). They were represented by a variable number of vessels, on average 3 to 4 arteries. Like their number, also, their caliber was very variable; those in the rostral position have a bigger caliber. Usually, they stemming at the rostral segment of the basilar artery and caudal segment of caudal communicating artery. The rostral cerebral arteries on each side were in communication by the accessory posterior communicating artery. They supplied the superior and inferior surface of the cerebellar hemisphere, the anterior and posterior corpora quadrigemina and the vermis.

CONCLUSIONS

The use of these techniques of latex injection and sections of the organs at different levels in this study allowed a better recognition of the arteries studied. The simple dissection with injection of colored latex in the structures to be identified allows the best location, and the study of the relation of the arteries with the organs of the region. In relation to results, our study confirm the results of Kanan.

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RESUMEN: En presente estudio se analizó la anatomía de las arterias del encéfalo en cinco camellos (*Camelus dromedarius*, Linnaeus 1758). Después de administrar una inyección intravascular de látex coloreado en la arteria carótida común se estudiaron las arterias incluyendo al círculo arterial del cerebro, sus ramas y uniones. Fueron descritos en detalle el curso y la distribución del suministro arterial al encéfalo y se realizó un análisis morfológico. La arteria basilar contribuyó al suministro de sangre del encéfalo del camello, diferenciando este aspecto en otras especies de Artiodactyla.

PALABRAS CLAVE: Anatomía; Vasos sanguíneos; Camelidae; Sistema circulatorio; Cerebral arterial circle.

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