The morphology of the circulus arteriosus cerebri in the ground squirrel (*Spermophilus citellus*)

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ABSTRACT: In this study, the circulus arteriosus cerebri of the ground squirrel (*Spermophilus citellus*) was investigated. Five ground squirrels were used as subjects. Coloured latex was injected from the left ventriculi of the hearts of all the squirrels. When the vertebral arteries of two of the animals were ligatured, it was found that there was no internal carotid artery. After careful dissection, the circulus arteriosus cerebri (the circle of Willis) was investigated. The right and left vertebral arteries gave rise to the caudal cerebellar artery before forming the basilar artery. The basilar artery formed the caudal communicans artery that was the caudal part of the circulus arteriosus cerebri on the pontocrural groove (sulcus pontocruralis). The caudal, medial, rostral cerebellar, the common root formed by the caudal cerebral and choroid arteries, the rostral choroid, the rostral and medial cerebral arteries arose from the vertebral, basilar and caudal communicans arteries and dispersed to the cerebrum and cerebellum from caudal to cranial. The termination and the branches of the rostral cerebral artery in ground squirrels varied. It was observed that the internal carotid artery does not supply the circulus arteriosus cerebri in ground squirrels.

Keywords: morphology; circulus arteriosus cerebri; brain; ground squirrel (*Spermophilus citellus*)

The rodents (Rodentia) which are the widest order of placental mammals, comprise more than half of all described mammals. The ground squirrels (*Spermophilus citellus*) are representatives of the Sciuridae family that constitutes a group of the order Rodentia (Karol, 1963; Weichert, 1970; Kuru, 1987; Demirsoy, 1992).

There have been many investigations on the vascularisation of the arteries which supply blood to the brain. Studies have been carried out in rats (Brown, 1966; Green, 1968), rats and mice (Firbas et al., 1973), mouse (Cook, 1965; Wiland, 1974; Szczurkowski et al., 2007), Guinea pigs (Ocal and Ozer, 1992), Guinea pigs and rabbits (Popesko et al., 1990), rabbits (Brehmer and Beleites, 1988), dogs (Miller et al., 1964), cats (McClure et al., 1973), porcupine (Aydin et al., 2005), Red squirrels (Aydin, 2008), Mongolian gerbils (Klachinka et al., 2008) and mole-rats (Aydin et al., 2008). According to our knowledge there are no investigations on the circulus arteriosus cerebri of the ground squirrel (*Spermophilus citellus*) and this is the first study on this subject in ground squirrels.

The purpose of this study was to document arteries that constitute the circulus arteriosus cerebri in the ground squirrel (*Spermophilus citellus*).

MATERIAL AND METHODS

Five adult ground squirrels, trapped by farmers, were used. After they were anaesthetized with penthathol (6 ml/kg), the cavum thoracis of all animals were opened and a 5 mm diameter, 7 cm long plastic pipe was placed into the left cardiac ventricle. The arterial blood was drained and red coloured latex was injected into the left ventriculi through this pipe. To see whether the internal carotid artery existed, the right and left vertebral arteries of 2 out of the five examined animals were ligatured when these applications were performed. After three days fixation of the whole bodies of the animals in 10% formalin, the skulls of the ground squirrels were placed in 10% hydrochloric acid for 24 h for decalcification and the skulls were then easily opened. The arterial patterns at the base of the brain were

examined and pictured. For the terminology, the Nomina Anatomica Veterinaria (1994) was used.

RESULTS

Blood supply to the brain was seen to be realised only by the vertebral artery in the studied ground squirrels. After giving rise to the caudal cerebellar artery the right and left vertebral arteries of the ground squirrels formed the basilar artery by joining to each other at the base of the medulla oblongata. On the crus cerebri the basilar artery was separated into two branches forming the caudal communicans artery. In the cranial part, sometimes the rostral cerebral arteries was joined to each other and formed the circulus arteriosus cerebri whilst in other instances they extended separately. There was no rostral communicans artery in these animals. The arteries which vascularised the cerebrum and cerebellum originated from the vertebral, basilar, and caudal communicans arteries and rostral cerebral arteries (Figures 1, 2, 3).

Arteries originating from the vertebral artery

The caudal cerebellar artery arose symmetrically from the vertebral artery and dispersed to the caudal part of cerebellum and ventriculus quartus.

Arteries originating from the basilar artery

The medial cerebellar artery arose symmetrically from the basilar artery and dispersed to the lateral part of the cerebellum by passing by the medulla oblongata.

The rostral cerebellar artery orginated symmetrically just before the formation of the caudal communicans artery and dispersed to the caudal of the tectum mesencephali and the cranial of the cerebellum.

Arteries originating from the caudal communicans artery

The caudal cerebral artery originated from the caudal communicans artery together with the choroid artery and after separating from the caudal communicans artery by passing through the caudoventral of the hemispherium to the dorsal of the brain, extended to the dorsal of the caudal part of the corpus callosum at the fissura longitudinalis cerebri and the terminal branches of this artery were anastomosed with the branches arising from the rostral cerebral artery at the caudal part of the facies medial cerebri.

The caudal choroid artery originated symmetrically as a single root together with the caudal cerebral artery from the caudal communicans artery. After separating from the caudal cerebral artery it gave off two branches at the lateral of the tectum mesencephali. The first branch dispersed to the tectum mesencephali and ventriculus tertius and the second branch dispersed to the tectum mesencephali and the cranial part of the cerebellum.

The internal ophtalmic artery did not originate from the circulus arteriosus cerebri in these animals and originated directly from the communis carotid artery and entered the cavum cranii, before arriving at the eye by passing through the lateral of the brain. Here it was fixed in the cavum cranii by the meninges. There was no connection between this artery and the circulus arteriosus cerebri.

The ramus hypophis extended to the gland hypophysis.

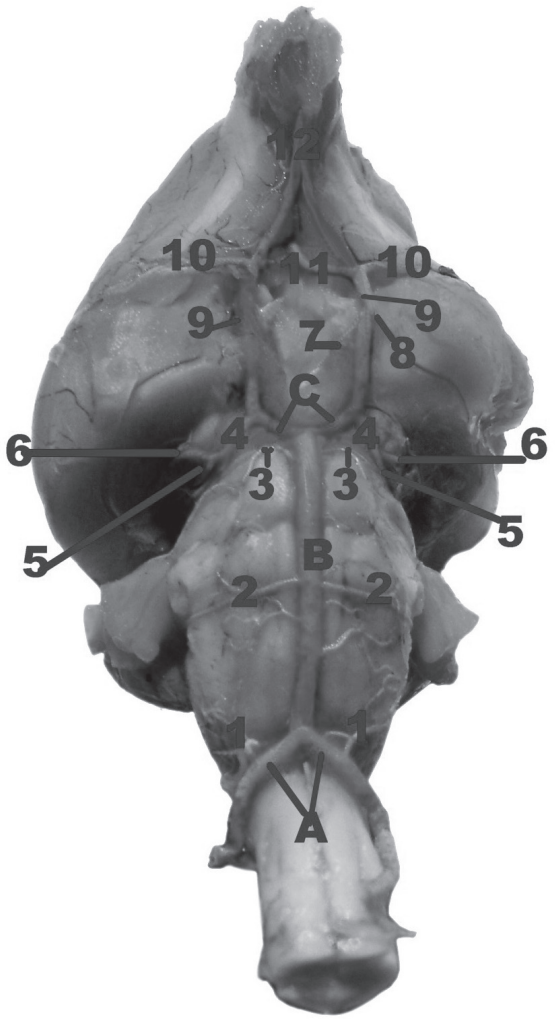
Arteries originating from the rostral cerebral artery

The rostral choroid artery originated from the rostral cerebral artery as a thin branch just before the medial cerebral artery and just after its origin extended under the lobus priformis to the ventriculus lateralis giving rise to small branches along its length.

The medial cerebral artery separated as a single branch from the middle part of the rostral cerebral artery and after giving off branches basal and lateral of the hemispherium it terminated by ramifying cortical and central branches at the facies convexa cerebri.

The rostral cerebral artery gave off the medial cerebral artery, then at the fissura longitudinalis cerebri a branch arising from the right rostral cerebral artery in three animals and from the left rostral cerebral artery in two animals, gave off branches to the cranial part of the corpus callosum, facies medialis cerebri and the medial of the dorsal part of the cerebrum and anastomosed with the terminal

1



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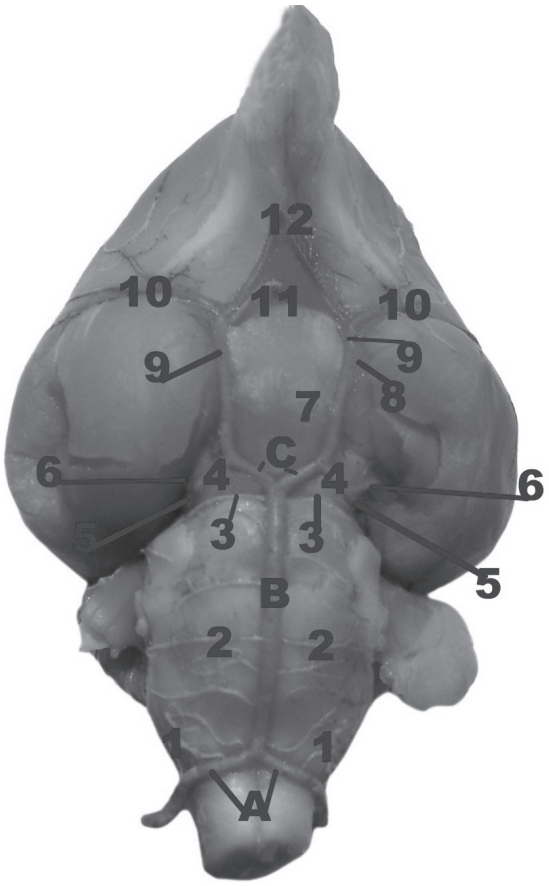

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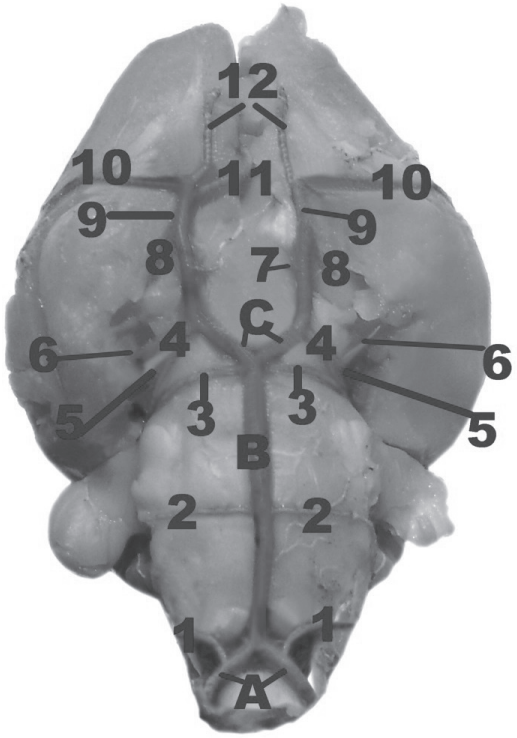

Figures 1 to 3. View from the base of the cerebrum of the circulus arteriosus cerebri in the ground squirrel (*Spermophilus citellus*)

A = vertebral artery, B = basilar artery, C = caudal communicans artery, 1 = caudal cerebelli artery, 2 = medial cerebelli artery, 3 = rostral cerebelli artery, 4 = common root formed by the caudal choroid and caudal cerebral artery, 5 = caudal choroid artery, 6 = caudal cerebral artery, 7 =Ramus hypophysis, 8 = rostral choroid artery, 9 = medial cerebral artery, 10 = rostral cerebral artery, 11 = branch which extended to facies cerebri media, 12 = internal ethmoidal artery

branches of the caudal cerebral artery. After giving off these branches, the right and left rostral cerebral arteries anastomosed with each other in the cranial in two animals (Figures 1, 2), and in three animals extended as the internal ethmoidal artery without anastomosing with each other (Figure 3).

DISCUSSION

It has been reported that the circulus arteriosus cerebri is formed by the basilar and the internal carotid artery in rats (Brown, 1966; Green, 1968), mice (Cook, 1965; Wiland, 1974), rabbits (Barone et al., 1973; Brehmer and Beleites, 1988), cats (McClure et al.,1973; Getty, 1975) and dogs (Miller et al., 1964; Getty, 1975) whereas according to Ocal and Ozer (1992), it is formed by the internal ophthalmic artery, the basilar artery and the internal carotid artery in Guinea pigs. We have previously reported in a study on porcupines (Aydin et al., 2005), and also in red squirrels (Aydin, 2008), that only the vertebral artery supplies the circulus arteriosus cerebri. The results presented in this study are in conformity with these earlier reports.

It has been reported that the caudal cerebellar artery originates from the basilar artery symmetrically in rabbits (Barone et al., 1973), mice (Wiland, 1974), dogs and cats (Getty, 1975) and mole-rats (Aydin et al., 2008) and asymmetrically in dogs (Miller et al., 1964), cats (McClure et al., 1973), guinea pigs (Ocal and Ozer, 1992), porcupines (Aydin et al., 2005). In this study, in contrast to all above reports it was observed that this artery originated from the vertebral artery.

According to Wiland (1974), the medial cerebellar artery is mostly single but sometimes ramifies as two or three branches and originates from the basilar artery asymmetrically in the mouse and its terminal branches are anastomosed with the caudal cerebellar artery. Getty (1975) in reference to the dog, and Aydin et al. (2005) in reference to the porcupine, describe it originating as a symmetrical single branch from the basilar artery, whilst in cats (Getty, 1975) it has been reported to be a continuation of the caudal cerebellar artery. Studies in red squirrels (Aydin, 2008), and mole-rats (Aydin et al., 2008) meanwhile, have reported the absence of this branch altogether. Similar to the description of Getty (1975) regarding dogs and Aydin et al. (2005) with regard to the porcupine, in these ground squirrels the medial cerebellar artery originated symmetrically as a single branch from the basilar artery.

It has been reported that the rostral cerebellar artery generally separates from the basilar artery, sometimes with one branch from the caudal communicans artery, the other branch asymmetrically from the basilar artery in the rat (Brown, 1966), and originates from the basilar artery (Popesko et al., 1990) or the caudal communicans artery in guinea pigs (Ocal and Ozer, 1992). It originates symmetrically from the basilar artery in the red squirrel (Aydin, 2008) and mole-rat (Aydin et al., 2008) and it also originates from the caudal communicans artery in mice (Wiland, 1974), rabbits (Barone et al., 1973), dogs (Miller et al., 1964) and cats (McClure et al., 1973). According to Getty (1975) the rostral cerebellar artery is a branch of the mesencephalic artery in dogs and cats. In the present study, the results are partly in corformity with the reports of Miller et al. (1964) with regard to dogs, McClure et al. (1973) regarding cats, Barone et al. (1973) on rabbits, Wiland (1974) on mice and Aydin et al. (2005) on porcupines. They are completely consistent with descriptions of the red squirrel (Aydin, 2008) and the mole-rat (Aydin et al., 2008) whilst they are not in agreement with descriptions of various other animals.

The choroid artery originates from the internal carotid artery in the rat (Green, 1968), and mole-rat (Aydin et al., 2008), as a single branch from the cranial part of the circulus arteriosus cerebri in mice (Wiland, 1974), and from the medial cerebral artery in dogs (Miller et al., 1964). Some authors have reported the presence of the cranial choroid artery in dogs (Miller et al., 1964; Getty, 1975), and the caudal choroid artery in cats (McClure et al., 1973; Getty, 1975), whilst both the caudal and cranial choroid arteries were reported to be present in the porcupine (Aydin et al., 2005) and the caudal choroid arteries showed variations while originating from the caudal communicans artery in red squirrels (Aydin, 2008). In this study, both caudal and cranial choroid arteries were present similar to our previous report on the porcupine (Aydin et al., 2005) and red squirrels (Aydin, 2008). Moreover, the caudal choroid artery and the caudal cerebral artery originated together from the caudal communicans artery; this is partly in conformity with the description of the red squirrel (Aydin, 2008) but has not been described in other reports.

The caudal cerebral artery originates from the caudal communicans artery in the rat (Green, 1968), the mouse (Winland, 1974), guinea pig (Popesko et al., 1990), rabbit (Barone et al., 1973; Popesko et al., 1990) and porcupine (Aydin et al., 2005). This artery originates from the junction of the caudal communicans artery with the basilar artery in the rat (Brown, 1966), and guinea pig (Ocal and Ozer, 1992). In the red squirrel (Aydin, 2008) it was reported that the caudal cerebral artery originated

sometimes from the caudal communicans artery by itself and sometimes originated together with the caudal choroid artery. These results are in partial agreement with this last report whilst differing from all others.

It has been reported that the internal ophtalmic artery is separated from the rostral cerebral artery in the dog (Miller et al., 1964; Getty, 1975), originates from the internal carotid artery in the rat (Green, 1968) from the middle of the medial part of the circulus arteriosus cerebri in porcupines (Aydin et al., 2005), whilst blood is supplied to the brain by the internal ophtalmic artery in guinea pigs (Ocal and Ozer, 1992). This artery was not connected to the circulus arteriosus cerebri in these ground squirrels.

The middle cerebral artery originates from the internal carotid artery in the dog (Miller et al., 1964; Getty, 1975) and mole-rat (Aydin et al., 2008), as a single branch from the circulus arteriosus cerebri in the mouse (Cook, 1965; Wiland, 1974), guinea pig (Ocal and Ozer, 1992), cat (McClure et al., 1973; Getty, 1975), and porcupine (Aydin et al., 2005), and from the rostral cerebral artery in the red squirrel (Aydin, 2008). It originates as two separate branches from the circulus arteriosus cerebri in the rat (Brown, 1966; Green, 1968; Firbas et al., 1973), mouse (Firbas et al., 1973), and rabbit (Popesko et al., 1990). Our results are in corformity with the statements in reference to the porcupine (Aydin et al., 2005) and red squirrel (Aydin, 2008).

It has been reported that two rostral cerebral arteries on occasion join together with a single branch (the rostral communicans artery; Miller et al., 1964; Brown, 1966; Green, 1968; McClure et al., 1973; Wiland, 1974; Getty, 1975; Popesko et al., 1990; Ocal and Ozer, 1992; Aydin et al., 2005) or with two branches (Brown, 1966; McClure et al.,1973) or do not join at all (Brown, 1966). In the red squirrel this was shown to vary (Aydin, 2008). In our study, the connections of the rostral cerebral arteries showed variations in ground squirrels similar to those observed in the red squirrel (Aydin, 2008).

The rostral cerebral artery has been reported to give branches which dispersed between the two hemispheres in the dog (Miller et al., 1964), cats and dogs (Getty, 1975), and rats (Brown, 1966). In addition to branching, the last part of this branch was reported to anostomose with the last part of the caudal cerebral artery between the two hemispheres in rats (Green, 1968), and mice (Wiland, 1974). In the red squirrel (Aydin, 2008), a branch from the right or left rostral cerebral artery and in one animal from the rostral communicans artery dispersed to the intern of the hemispheriums and anastomosed with terminal branches of the caudal cerebral arteries. In the present study, similar to what was described in red squirrels (Aydin, 2008), the branch arising from the right or left rostral cerebral artery dispersed into the hemispheriums and anastomosed with terminal branches of the caudal cerebral artery at the caudal of the facies medialis cerebri.

In addition to the internal ethmoidal artery, the internal ophtalmic artery arises as the last branch of the rostral cerebral artery in cat and dogs (Getty, 1975), and in dogs (Miller et al., 1964). According to studies in the rat (Brown, 1966), and mouse (Wiland, 1974), the last branch of the rostral cerebral artery is the internal ethmoidal artery. In red squirrels (Aydin, 2008) it was observed that the rostral cerebral arteries formed the ethmoidal artery sometimes as separate branches. In ground squirrels the last branch of the rostral cerebral artery was the ethmoidal artery and this result is partly in conformity with those of Brown (1966) and Wiland (1974). The right and left rostral cerebral artery formed the ethmoidalis artery sometimes by joining to each other and sometimes separately in this study and this observation is in conformity with those of Aydin (2008), whilst differing from all other reports.

In conclusion, it was found that, in contrast to many previous reports on other animals, in ground squirrels the caudal cerebellar artery originates from the vertebral artery and the caudal choroid artery originates from the caudal communicans artery together with the caudal cerebral artery. The right and left rostral cerebral arteries were seen to be both connected and not connected to each other at the cranial of the circulus arteriosus cerebri; the branch extending to the facies medial cerebri sometimes originated from the right and sometimes from the left rostral cerebral artery, while the internal coroid artery was seen to be absent in the ground squirrel.

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