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Arteries of the Brain in Wild European Rabbit *Oryctolagus cuniculus* (Linnaeus, 1758)

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Research into the pattern and variation of brain arteries in wild rabbit involved 43 brains. The main source of blood supply to the brain in rabbit are vertebral arteries and the basilar artery, formed as a result of their anastomosis, as well as internal carotid arteries the branches of which form the arterial circle of the brain. Variation in descent concerns mostly the pattern of descent of middle cerebral arteries, in 36.5% they were multiple vessels. The caudal communicating arteries in wild rabbit constituted a symmetrical anastomosis of internal carotid arteries and caudal cerebral arteries. They stabilized an even blood supply to all parts of the brain. The caudal cerebral arteries constituted the terminal branches of the basilar artery. A comparison of the blood supply to the brain in wild rabbit and domestic rabbit described by WILAND (1968) revealed lower variation in the arteries in the wild form than in the domestic rabbit.

Key words: Artery, brain, European rabbit.

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The rich literature on the blood supply to the brain describes the arteries of the cerebral base in species representing the taxonomic order *Lagomorpha*. The first description of the arteries of the cerebral base in domestic rabbit can be found in HOFFMANN (1900). The author limited the study to the description of the pattern of arteries based on a few individuals. The pattern of the arteries in domestic rabbit and their variation, involving abundant material, were researched by WILAND (1968). A comparison of the arteries of the brain in insectivores, primates, rodents and lagomorphs was provided by BUGGE (1974) and BARONE (1996), presenting diagrams with the arteries of the cerebral base in domestic animals which also included the arteries of the cerebral base in domestic rabbit. WILAND *et al*. (1987) also investigated the pattern and variation in the arteries of the cerebral base in brown hare. GILLILAN (1972) described the arteries of the brain in primitive mammals and found that the cortical branches in the middle cerebral artery run on the surface of the telenecephalon and do not ascend into the sulci. The author's research involved numerous rodents as well as the brains of hare and domestic rabbit.

Among the mammalian species investigated so far, there was found, on the one hand, some similarity in the anatomy and the pattern of arteries in the brain and, on the other hand, considerable variation in the configuration of brain arteries. Research reported by BROWN (1966) and JABŁOŃSKI (1975) which involved the laboratory rat, WILAND (1974) – laboratory mouse, FIRBAS *et al*. (1973) hamster, JABŁOŃSKI and BRUDNICKI (1984) muskrat, and KUCHINKA *et al*. (2008) Mongolian gerbil, show that the greatest variation in those species concerns the pattern and method of communicating with other vessels of caudal arteries. Important information on the blood supply to the brain can be acquired by a comparison of domesticated and wild forms in mammals. Such an opportunity is created by the species investigated herein. We have described the variation in the arteries of the brain in the wild form of the rabbit. The aim of this paper is to investigate the pattern and the variation in the arteries of the brain in wild rabbit

and perform a comparison with the arteries of the brain described in domestic rabbit as well as with other mammalian species studied so far.

Material and Methods

The research involved 43 wild rabbit brains. The arteries of 38 individuals were filled with synthetic latex introduced via a syringe to the left ventricle under fixed pressure. Additionally in 5 individuals the common carotid arteries were tied up, in those cases latex reached the brain through the clavicular arteries and the vertebral arteries. The experiment aimed at determining to what extent the blood supplied by vertebral arteries reaches the arteries descending from the basilar artery, mostly whether it reaches the caudal communicating arteries and the front part of the arterial circle of the brain. After fixation in 5% formalin solution and removal of the brain from the cranial cavity, the arteries were prepared and then photographed.

Results

The brain in rabbit is blood-supplied by internal carotid arteries and vertebral arteries. The vessels, through a system of branches and anastomoses, form two main vascular systems at the base of the brain: the arterial circle of the brain and the basilar artery. The internal carotid artery, after perforating the dura mater, changes into the rostral cerebral artery and, caudally, gives rise to the caudal communicating artery. The rostral choroidal artery first descends from the rostral cerebral artery which then ascends under the piriform lobe. The internal olphthalmic artery descends at the same level medially. Another, and the most robust, branch of the rostral cerebral artery is the middle cerebral artery. The descent of the middle cerebral artery was in 28 (73.7%) individuals asymmetric. Above the descent of the main trunk of the middle cerebral artery, minor branches symmetrically descend onto the olfactory triangle.

The middle cerebral artery and its cortical branches are supplied by the telencephalon. Already after the descent from the parent vessel, a caudal branch supplies blood to the piriform lobe. SKOCZYLAS (2000) defined these branches as temporal arteries.

Slightly above the main trunk of the middle artery, caudally, branches descend onto the frontal lobe. At the same height three or four cortical branches descend onto the parietal lobe. Rostral cerebral arteries run further towards the median sulcus and this is where they communicate into a single callosal artery. From a short section of asymmetrical callosal artery that descends there, already at the median cerebral fissure, the internal ethmoidal arteries which return onto the ventral surface of the brain and run along the medial margin of tracts. The caudal communicating arteries of the brain form the caudal-lateral part of the arterial circle of the brain. They run parallel to the medial margin of the piriform lobe, going towards the cerebral peduncles of the brain. Here they communicate with posterior cerebral arteries, thus closing the arterial circle of the brain from the caudal side. The basilar artery is formed as the result of the anastomosis of well-developed vertebral arteries. It is the best-developed artery at the base of the brain in rabbit. Numerous and symmetrical arteries branch off onto the medulla oblongata and then the caudal cerebellar arteries which also descend symmetrically. In this area labyrinthine arteries usually descend from the caudal cerebellar arteries. Above the opening of the caudal cerebellar arteries, successive minor arterial branches descend onto the pons. At the height of the anterior margin of the pons, the basilar artery gives off rostral cerebellar arteries. The arteries on the lateral surface of the pons divide into a branch reaching the anterior surface of the cerebellum and a well-developed artery running on the ventral surface of the paraflocculus. Slightly above the opening of the rostral cerebellar arteries well-developed caudal cerebral arteries descend and communicate with caudal arteries. Above the communication with the caudal communicating artery, the caudal cerebral arteries get divided into two or three terminal branches.

As compared with the presented anatomy and the pattern of the arteries at the base of the brain, in rabbit variation was observed which can be referred to as variation in the pattern of descent and the asymmetry in the anatomy of respective arterial vessels. The arterial circle of the brain varies clearly between the anterior part, formed by rostral cerebral arteries and the posterior part, made up of caudal communicating arteries and the initial sections of the caudal cerebral arteries. In two (5.26%) individuals an open-on-the-left arterial circle of the brain was observed. In these brains the full bloodstream was directed to the middle cerebral artery and its cortical branches. The middle cerebral artery usually descended with a single trunk, however in 14 (36.5%) individuals from the rostral cerebral artery two or three arterial vessels descended asymmetrically which then divided on the surface of the cortex. Such a pattern of descent can be referred to as multiple middle cerebral arteries. The caudal communicating arteries showed a regular pattern. They connected the internal carotid arteries with the caudal cerebral arteries. The vessels were clearly thinner than the rostral cere-

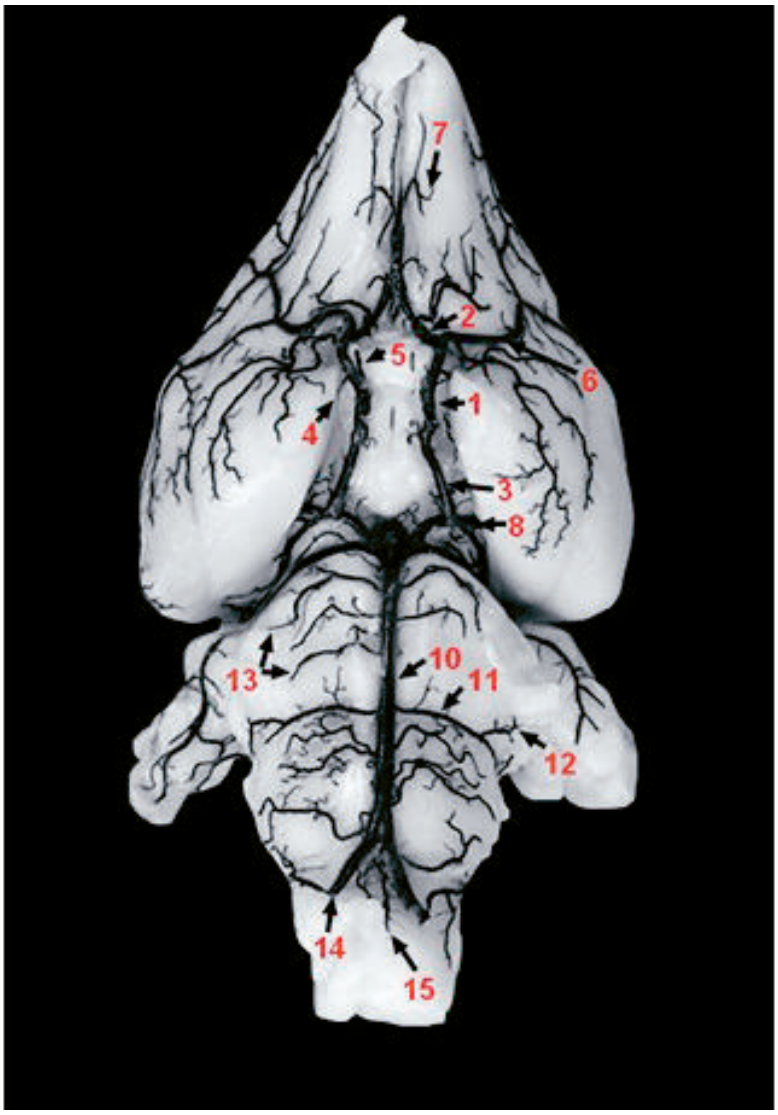

Fig. 1. Arteries of the base of the brain in rabbit. 1 – Internal carotid artery, 2 – rostral cerebral artery, 3 – caudal communicating artery, 4 – rostral choroid artery, 5 – internal ophthalmic artery, 6 – middle cerebral artery, 7 – internal ethmoidal artery, 8 – caudal cerebral artery, 9 – rostral cerebellar artery, 10 – basilar artery, 11 – caudal cerebellar artery, 12 – labyrinthian artery, 13 – pontine and medulla oblongata branches, 14 – vertebral artery, 15 – ventral spinal artery.

bral arteries and the caudal cerebral arteries. Running along the inner margin of the piriform lobe, in the caudal part, they diverged from one another, giving a specific shape to the posterior part of the arterial circle of the brain. The pattern and the way of communicating of both vascular systems demonstrated a high regularity. However, variation was observed in the pattern of division into the terminal branches of the caudal cerebral arteries. Above the descent of the caudal communicating arteries, the caudal cerebral arteries branched two or three times.

One of these, located most rostrally, ascended into the cerebral cortex, the other one, descending more caudally, ran on the dorsal part of the peduncles of the brain and branched terminally onto the occipital lobe. In two individuals (5.26%) the symmetrical caudal cerebral arteries descended from the right-side rostral cerebellar artery. Variation in descent was also recorded for the rostral cerebellar arteries. In 20 (52.5%) brains they descended as symmetrical double vessels at the place where the basilar artery divided into the caudal cerebral arteries. In those cases one of the arteries ran towards the paraflocculus and on its surface was divided into cortical branches. The other artery supplied blood to rostral and dorsal surfaces of the cerebellum. In the other 18 (47.5%) cases the rostral cerebellar arteries descended from the basilar artery with a single trunk and then divided into two branches running further as discussed before.

Tying up the common carotid arteries made it possible to track down the range of the blood supplied by the vertebral arteries to the brain. In those

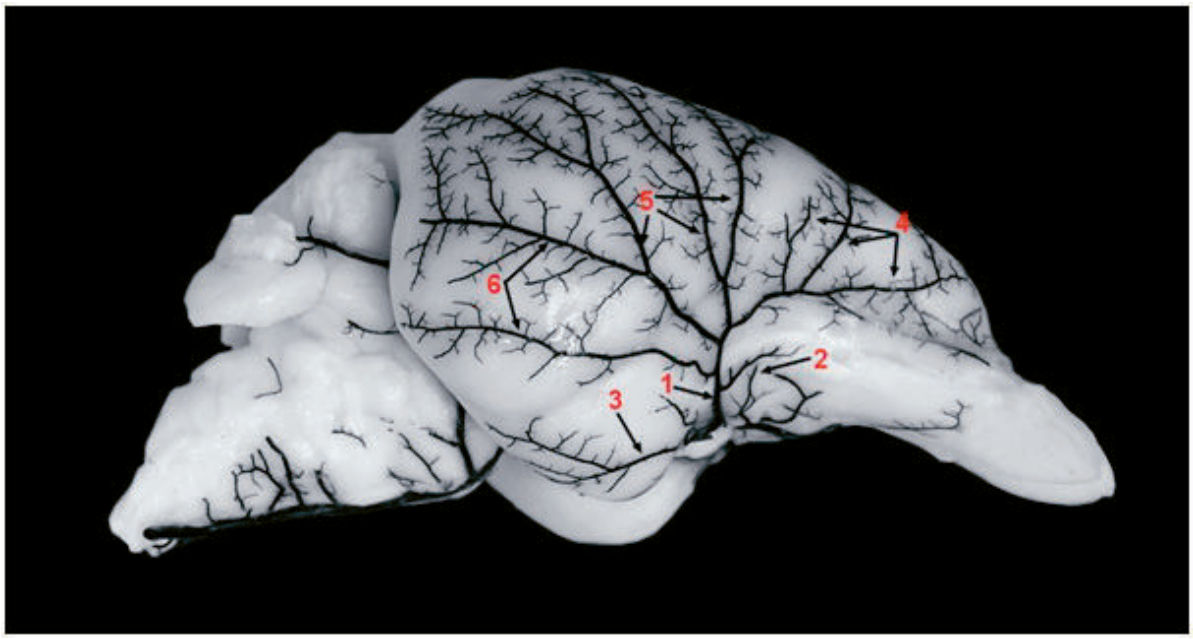

Fig. 2. Middle cerebral artery and its cortical branches. 1 – medial cerebral artery, 2 – anterior olfactoral artery, 3 – posterior olfactoral artery, 4 – frontal branches, 5 – parietal branches, 6 – temporal branches.

cases the basilar artery and its direct branches were well-filled with latex which reached, in this way, the branches onto the medulla oblongata and the pons as well as the arteries supplying the cerebellum. The latex also filled in the caudal cerebral arteries, thus showing their range. It also slightly filled the caudal communicating arteries (Fig. 3). The terminal sections of the cortical branches of caudal cerebral arteries reached the surface of the parietal lobe.

Discussion

The observations show that the pattern of the arteries at the base of the brain in wild rabbit, in general, corresponds to the pattern in other mammalian species. At the base of the brain two separate brain blood supply systems can be differentiated. The first is composed of the arterial vessels constituting the branches of the internal carotid artery, the other one comprises the

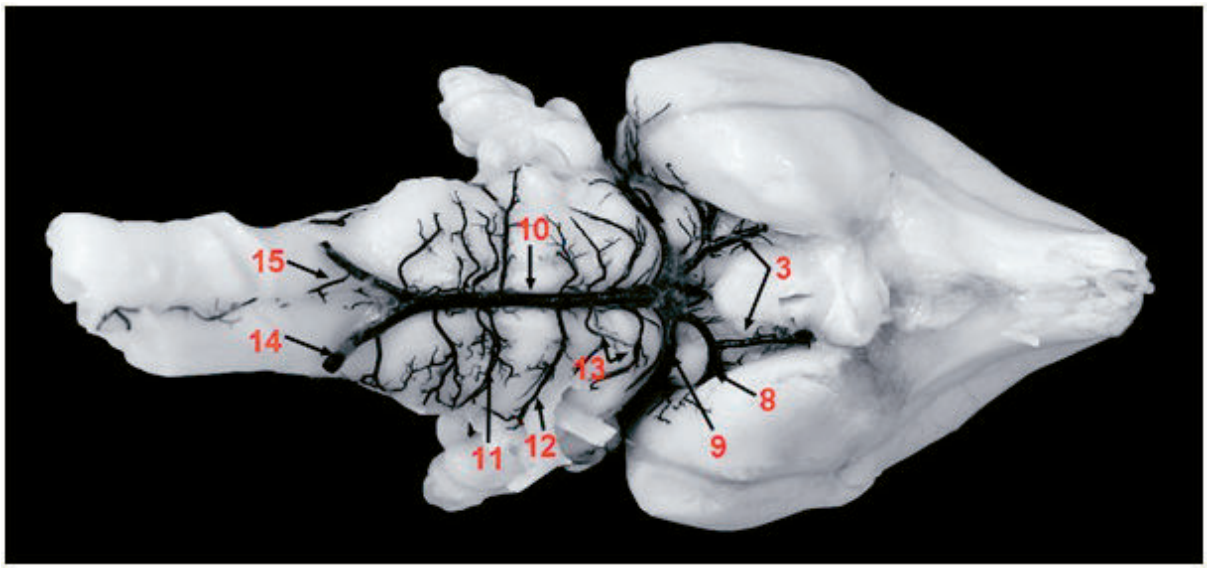

Fig. 3. Brain base arteries filled with latex introduced through the left chamber of the heart in an individual with closed common carotid arteries. 3 – caudal communicating artery, 8 – caudal cerebral artery, 9 – rostral cerebellar artery, 10 – basilar artery, 11 – caudal cerebellar artery, 12 – labyrinthian artery, 13 – pontine and medulla oblongata branches, 14 – vertebral artery, 15 – ventral spinal artery.

branches of the basilar artery formed as a result of the anastomosis of vertebral arteries. The two main systems anastomose the caudal communicating arteries. Observations into the arteries of the base of the brain in wild rabbit showed a species-characteristic shape of the arterial circle of the brain which is hourglass-like. In wild rabbit, similarly as in the domesticated form, the best-developed artery at the base of the brain was the basilar artery which in all individuals was formed as a result of the anastomosis of symmetrical equally well-developed vertebral arteries. Unlike in the domesticated form reported by WILAND (1968), the shape of the arterial circle of the brain showed a high regularity, as did the pattern of descent of the middle cerebral arteries and caudal cerebral arteries. An open cerebral circle of the brain was observed in a single individual, whereas in domestic rabbit in 10% of the individuals as noted by WILAND (1968).

The same author considers the caudal cerebral arteries to be the branches of the caudal communicating arteries. The experiment of closing the common carotid arteries shows, at the same time, that the caudal cerebral arteries in rabbit are supplied with blood by the basilar artery and the blood reaches the occipital lobe of the brain in that way. A similar pattern of descent of the caudal cerebral arteries occurred in 28.8% cases in European pine vole (BRUDNICKI 1994). In brown hare, closely related to rabbit, the caudal cerebral arteries consisted of multiple vessels on both sides. Multiple caudal cerebral arteries were described in ruminants (BRUDNICKI 2000; FRĄCKOWIAK & JAKUBOWSKI 2008; DING *et al*. 2007) and it was a rule in that group of animals. Some authors described the branch ascending deep into the cerebral cortex as the choroidal artery of the third ventricle. Observed in rabbit, the variation in the descent of middle cerebral arteries is also found in other animal groups. The middle cerebral arteries descended symmetrically as multiple arterial vessels in 36.5% of the cases.

The pattern of descent of rostral cerebellar arteries described in rabbit was found in domestic rabbit, hare and some rodent species; it occurred e.g. in rat, as reported by JABŁOŃSKI (1975), bank vole – by BRUDNICKI *et al*. (1991) European pine vole – as reported by BRUDNICKI (1994).

The arteries of the base of the brain in wild rabbit, despite a general similarity of the pattern of those arteries in the mammalian species studied so far, demonstrate specific and separate characteristics of the anatomy of these vessels; an unusually rich network of arteries supplying blood to the brain trunk, an abundant vascular network supplying blood to the telencephalon and the proportionally less developed caudal communicating arteries. The caudal communicating arteries in wild rabbit constituted a symmetrical anastomosis of the internal carotid arteries and caudal cerebral arteries, stabilising an even blood supply to all the parts of the brain.

The experiment of tying up the common carotid arteries made it possible, to some extent, to determine the route of blood supply of some arteries; it shows clearly that in rabbit the caudal cerebral arteries receive blood via the basilar artery. The fixed pressure at which the vessels were filled through the left ventricle allows for filling with latex the basilar artery and its branches and, to a slight extent, the caudal communicating arteries. It did not allow, however, for filling of the anterior part of the circle and thus the rostral cerebral arteries and the middle cerebral arteries. This also confirms the thesis of a relative separation of both brain blood-supplying systems. The caudal cerebral arteries constituted the terminal branches of the basilar artery in man (BAPTISTA 1964) and other primates (JOU 1968; WILAND & BRUDNICKI 1979; ROSKOSZ & JABŁOŃSKI 1984)

An examination of the brain blood-supply in wild rabbit and a comparison with the brain blood-supply in domestic rabbit investigated earlier by WILAND (1968), revealed lower variation in the arteries in the wild form. Similar suggestions were reported by WILAND (1980) who compared red fox with the breeding forms, silver fox and platinum fox, and JABŁOŃSKI *et al*. (1989) who described the blood supply to the brain in wild boar and compared it to the blood supply to the brain in domestic pig.

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