The Morphology of the Brain Base Arteries in the Sparrowhawk (*Accipiter nisus*)

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ABSTRACT

This study was aimed at determining the vascular structure of the brain base arteries in the sparrowhawk. For this purpose, ten hawks were used. Latex injection method was applied to the materials. After careful dissection, the brain base arteries were investigated. The right and left internal carotid arteries were present in all of the samples. The cerebral carotid arteries were located in the sphenoid bone. The right and left cerebral carotid arteries formed an intercarotid anastomosis, placed ventro-caudal to the hypophysis. This anastomosis was a side-to-side anastomosis in a 'X' shape. Both the right and left caudal branches of cerebral carotid artery developed the basilar artery. The rostral branch was a continuity of the cerebral carotid artery latero-rostrally in the way of the ventral surface of the cerebral hemisphere. The rostral branch gave off the caudal cerebral artery, the dorsal tectal mesencephalic artery, the middle cerebral artery, the cerebroethmoidal artery, the rostral cerebral artery and the ethmoidal artery, during its course. It was hoped that our study will increase knowldege regarding the structural data on exotic birds since the literature relating to this species specific vascular anatomy in wild birds is lacking.

Keywords: Brain base arteries; Intercarotid anastomose; Morphology; Sparrowhawk.

INTRODUCTION

Quail hunting with sparrowhawks is commonly used in northeastern Turkey. In the avian taxonomy, the sparrowhawk is known as *Accipiter nisus*. It is a small bird of prey from the family *Accipitridae*. Throughout the world there are 50 different species of the genus *Accipiter.* The sparrowhawk is a major predator of small birds, especially sparrows (1).

The fundamental structure of the central nervous system of birds corresponds to that of the other vertebrates. The fully developed avian brain is divided into the following regions, from rostral to caudal: the forebrain, the midbrain and the hind brain (2). Degeneration of cerebral circulation causes nervous disorders (3). Arterial blood is supplied to the brain by paired carotid arteries which run medially in the neck before spreading laterally and dividing into external and internal branches. The internal carotids then run rostro-medially in the carotid canals before turning dorso-medially to pass into the distal sella turcica. Here an intercarotid anastomosis is formed (4). This communication between the right and left internal carotids is by means of a transverse connecting vessel or side to side anastomosis. Functionally, this anastomosis is the equivalent of the mammalian Circle of Willis (5). There were some studies on the brain arterial vascularization of birds, such as: Crowe and Crowe (1979) in helmeted guinea fowl (6), Midtgard (1984) in seagull (7), Campos (1987) in fowl (8), Holliday *et al*. (2006) in flamingo (9), Carvalho and Campos (2011) in Turkey (10) and Nazer and Campos (2011) in ostrich (11). In other species particularly wild birds there is a dearth of information (12-14). To the beset knowledge of the authors, no literature is available in relation with the brain arterial vascularization of raptors.

The aim of this study was to research the anatomical structure of brain base arteries in sparrowhawk (*Accipiter nisus*), with the hope that described investigations will help in understanding the vascular formation of the brain in wild birds. These results may consequently boost and contribute to the avian literature in veterinary anatomy.

MATERIAL AND METHODS

This study was carried on a total of 10 wounded and clinically terminal sparrowhawks that were received from the animal hospital at Atatürk University, Faculty of Veterinary Medicine, Erzurum, Turkey and provided by certified hunters in the Rize province. Their weights of the birds ranged from 150 to 250g. Under deep anesthesia using a xylazine-ketamine combination, the chest cavities of the hawks were opened and apex of their hearts was cut off to drain the blood. As stated in literature, vessels were cleaned out by administering 0.9 % NaCl through the aortae (15). Coloured latex (ZPG 582-G) was injected into left ventricle of heart. Materials were kept in 10% of formaldehyde solution at room temperature for 2-3 days for the latex to freze. Then, dissections were carried out and the pictures were taken. Nomina Anatomica Avium (5) was used for designation of anatomical terms.

The present study was approved on 22 April 2011 by the Atatürk University Local Ethical Committee for Animal Experiments (Approval #4).

RESULTS

Arterial blood was found to be provided to the brain by coupled carotid arteries which proceeded medially in the neck before spread laterally and dividing into external and internal carotid arteries. In all of the samples, the course of the right and left internal carotid arteries ran to the middle of the ventral side of the neck, perforating through the cervical carotid canal before they reached the nearness of the brain base. At this level they left the canal, deviated latero-cranially, proceeded as the cerebral carotid artery. The right and left internal carotid arteries were present in all of the samples exhibiting the bicarotid form.

Both the right and left cerebral carotid arteries in all of the samples were located in the sphenoid bone running through the cranium (Figure 1/1, 2, 4, 5; Figure 2/3). This segment consisted of the intrasphenoid segment of the artery. From this point each cerebral carotid artery deviated craniomedially to form an intercarotid anastomosis, located ventrocaudal to the hypophysis and on the near caudal aspect of the optic chiasma (Figure 1/3). This anastomosis was determined as a side-to-side anastomosis in a 'X' shape (Figure 1/3). The right and left cerebral carotid arteries at the level of the tuber cinereum divided into two terminal branches, the caudal and rostral branches (Figure 1/6; Figure 2/4, 6). The caudal branch of cerebral carotid artery continued caudoventrally after its origin producing a collateral branch, ventral tectal mesencephalic artery laterally and this branch distiributed to the ventral surface of the optic lobe. Then the right and left caudal branch of cerebral carotid artery in all of the birds continued caudomedially and developed basilar arteries at the level of the ventral interpeduncular fossa (Figure 2/1). This artery (basilar artery) extended itself caudally, on the ventral median fissure where it gave its collateral branches, the right and left rostral ventral cerebellar artery (Figure 2/2).

The rostral branch of the cerebral carotid artery was a continuity of the cerebral carotid artery, after the distribution the caudal branch, latero-cranially in the course of the cerebral hemisphere. This vessel continued latero-cranially, as an arch, until it reached the cerebral transverse fissure between the optic lobe and the cerebral hemisphere. At this level, it gave off its first collateral branch, the caudal cerebral artery in six of the birds (Figure 1/7). In these samples the caudal cerebral artery gave off its terminal branch the dorsal tectal mesencephalic artery in the cerebral transverse fissure. In four of the birds the caudal cerebral artery originated from rostral branch of cerebral carotid artery prior to the cerebral transverse fissure (Figure 2/7) and gave off the dorsal tectal mesencephalic artery at the level of the cerebral transverse fissure on the ventral surface of the optic lobe (Figure 2/8). The dorsal tectal mesencephalic artery dispersed to the ventral and cranial surface of the optic lobe.

In all of the samples, the second collateral branch of rostral branch of the cerebral carotid artery was the middle cerebral artery (Figure 1/8; Figure 2/9). This vessel continued rostrolaterally and medially in the ventral surface of the cerebral hemisphere, from the optic tract until the vicinity of lateral surface of olfactory bulb. During this course, it emitted several lateral hemispheric terminal branches which ascended the lateral surface of the cerebral hemisphere. The medial terminal branches of the middle cerebral artery and the terminal branches of the rostral cerebral artery approached to the ventral surface of the cerebral hemisphere.

After the formation of the middle cerebral artery, the rostral branch of cerebral carotid artery, in the base of the cerebral hemisphere deviated medially and extended as the cerebroethmoidal artery (Figure 1/9; Figure 2/10). The cerebroethmoidal artery was present in all but six of the samples, in the ventral surface of the right cerebral hemisphere where this vessel was residual or too short. In these samples, the right cerebroethmoidal artery appeared as the common root of the rostral cerebral and ethmoidal artery (Figure 1/9). However, in the remaining four samples, the right and left cerebroethmoidal artery was well developed extending medially from the middle cerebral artery, at the ventral surface of the cerebral hemisphere, to the ethmoidal artery (Figure 2/10).

The rostral cerebral artery, a collateral branch of the cerebroethmoidal artery, was a vessel rostrally extended from the cerebroethmoidal artery, on a ventral region of the cerebral hemisphere, restrained by the cerebral longitudinal fissure, the middle cerebral artery and the ethmoidal artery until it attained rostrally to the olfactory bulb (Figure 1/10; Figure 2/11). The right and left rostral cerebral arteries divided into two branches medially and laterally, just after its origin in four of the samples and medial branches continued rostromedially towards the cerebral longitudinal fissure (Figure 2/11). However, in six of the samples, the right rostral cerebral artery was single vessel. In these birds, the left rostral cerebral artery was a bifurcate vessel (Figure 1/10).

The ethmoidal artery was found to be the continuation of the cerebroethmoidal artery after the distribution of the rostral cerebral artery (Figure 1/11; Figure 2/12). The vessel continued ventrally and rostrally coursing the cerebral longitudinal fissure leaving the cranium across the olfactory foramen and finally distributing into the nasal cavity.

DISCUSSION

There is a dearth of literature regarding the sparrowhawk brain vascularization. Investigations on this topic concentrate on other birds (2, 4-6, 9, 10). Therefore, in this study we attempted to carry out an evaluation with this species of bird.

In sparrowhawks, it was observed that arterial blood was provided to the brain by coupled carotid arteries which proceeded medially in the neck before spread laterally. The same structures was reported for Japanese quail by Sharp and Follett (1969) (4) and for helmeted guineafowl by Crowe and Crowe (1979) (6). In some references, it was stated that birds may be bicarotid or unicarotid with regards to whether they

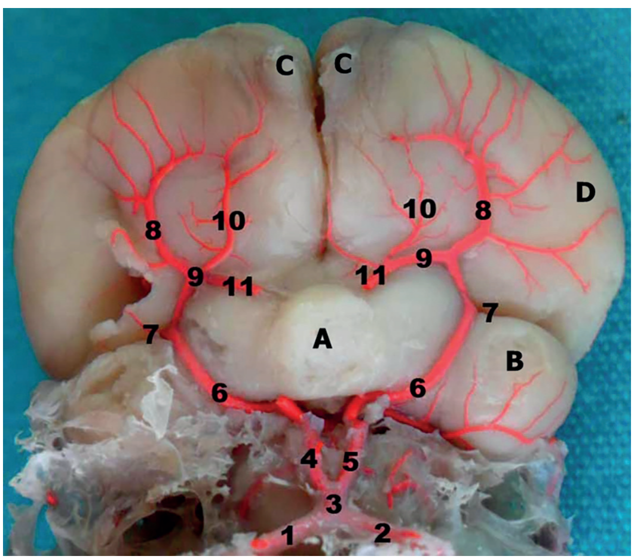

Figure 1: Ventral view of the brain base arteries and intercarotid anastomosis in sparrowhawk after removal of the hypophysis. 1, 2, 4, 5: Cerebral carotid artery, 3: Intercarotid anastomosis, 6: Rostral branch of the cerebral carotid artery, 7: Caudal cerebral artery, 8: Middle cerebral artery, 9: Cerebroethmoidal artery, 10: Rostral cerebral artery, 11: Ethmoidal artery, A: Optic chiasm, B: Optic lobe, C: Olfactory bulb, D: Cerebral hemisphere.

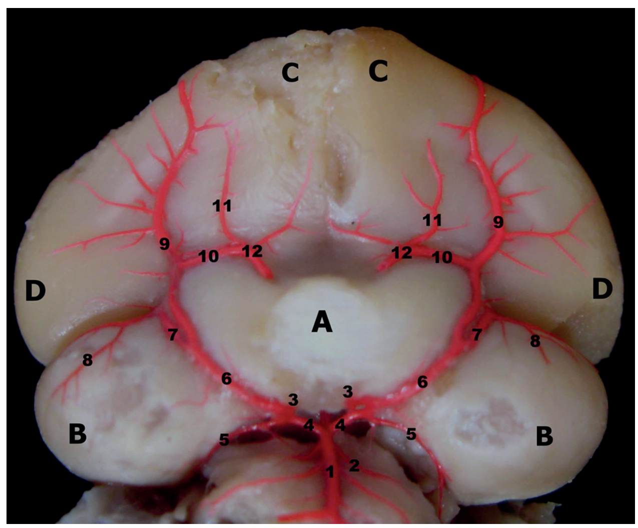

Figure 2: Ventral view of the brain base arteries in sparrowhawk after removal of the hypophysis. 1: Basilar artery, 2: Rostral ventral cerebellar artery, 3: Cerebral carotid artery, 4: Caudal branch of the cerebral carotid artery, 5: Ventral tectal mesencephalic artery, 6: Rostral branch of the cerebral carotid artery, 7: Caudal cerebral artery, 8: Dorsal tectal mesencephalic artery, 9: Middle cerebral artery, 10: Cerebroethmoidal artery, 11: Rostral cerebral artery, 12: Ethmoidal artery, A: Optic chiasm, B: Optic lobe, C: Olfactory bulb, D: Cerebral hemisphere.

have the right and left internal carotid arteries or not (5, 16). Both the right and left internal carotid arteries were present in the sparrowhawks investigated in present study. Therefore, they exhibited the bicarotid form with the right and left cerebral carotid arteries originating from the right and left internal carotid arteries, respectively. From our observations in the present study, we believe that this situation might be specific for the species.

The left and right cerebral carotid arteries of most avian species are combined to each other by an intercarotid anastomosis (14, 17-21). Some literature reported that the cerebral carotid artery continued rostro-medially into the carotid canal and caudal to the hypophysis the two arteries were combined by the transverse intercarotid anastomosis (8, 22, 23). Baumel and Gerchman (4) determined patterns of intercarotid anastomosis, called H, X and I types and Aslan *et al.* (12) reported two principal shapes of intercarotid anastomosis, namely H and X types. The latter authors included the turkey and goose in their study and found a side-to-side anastomosis like 'X' shape. Their findings were also found in the present study in the sparrowhawk.

Nickel *et al.* (2) reported that caudal to the hypophysis, caudal branches of the cerebral carotid artery united to become the basilar artery in domestic birds. Baumel and Gerchman (24) reported bilateral symmetry in origin and size of these vessels in nine out of 82 passerine birds which they examined. In accordance with the previous studies we found also that caudal branches of the cerebral carotid artery was bilaterally symetrical in origin and they united to become the basilar artery at the level of the ventral interpeduncular fossa in the sparrowhawk. However, in the white-crowned sparrow, the basilar artery mostly originated from the right caudal branch (14), while in the domestic fowl, primarily from the left caudal branch (19, 25) and the basilar artery was formed by only the right caudal branch in the Denizli rooster, domestic fowl, and goose while only the left caudal branch constituting basilar artery in the pheasant, silver pheasant, and turkey (12).

The ventral tectal mesencephalic artery of the sparrowhawk continued caudolaterally into the inside of the fissure that spreads to the optic lobe from the rhombencephalon which vascularized ventrally the ventrocaudal surface of optic lobe, as stated by Richards (1967), Campos (1987), Campos et al. (1995) (8, 19, 23) and Nazer and Campos (2011) (26). The ventral tectal mesencephalic artery originated from the caudal branch of the cerebral carotid artery in the sparrowhawk in this study while for Midtgard (1984) (7) studying the gull, the ventral tectal mesencephalic artery originated from the rostral branch of the cerebral carotid artery. The authors surmise that this anatomical situation may result in an increased perception of sight.

It was reported that the rostral branch of the cerebral carotid artery was a natural continuation of the cerebral carotid artery and bulged in the form of an arch, until it reached the cerebral transverse fissure (8, 23, 27). The results of our study also resembles these findings. As indicated by Midtgard (1984) (7) and Holliday (2006) (9) the rostral branch continued rostrally and spread the caudal cerebral artery, the middle cerebral artery, the ethmoidal artery and rostral cerebral artery.

Literature reports have documented that the caudal cerebral artery originated from the rostral branch of the cerebral carotid artery, close to the transverse fissure of the brain, between the optic lobe and the cerebral hemisphere (19, 27). According to Campos (8, 23, 28), the caudal cerebral artery originated from the rostral branch of the cerebral carotid artery at the level of the transverse fissure of the brain. In our study, these same finding were also found in six of the sparrowhawks examined. For Campos (1987) (8), in 3.3% of the cases, the right caudal cerebral artery originated from the rostral branch before it reached the transverse fissure. Similar determinations were found, in the remaining four samples in our study both in the right and left the caudal cerebral artery, in the sparrowhawk.

Studies from a number of authors (2, 8, 19, 23, 29), indicated that the middle cerebral artery in *Gallus gallus* constituted a belt which reached the olfactory bulb without leaving the ventral surface of the cerebral hemisphere. In the sparrowhawk, in addition to these findings, it also formed on its route, innumerable lateral hemispheric branches. In contrast to the ostrich (26), these lateral hemispheric branches in the sparrowhawk did not anastomose to the dorsal hemispheric terminal branches of the interhemispheric artery.

Carvalho and Campos (10) reported that the cerebroethmoidal artery was always present as a single vessel, of large caliber in the turkey. In contrast to this finding, in six of the samples in our study, in the ventral surface of the right cerebral hemisphere, the right cerebroethmoidal artery was residual or consisted of a short vessel. As claimed by Nazer and Campos (2011) (26) the rostral cerebral artery was a well developed vessel projected from the cerebroethmoidal artery in our study. Some researchers (6, 7, 9, 22, 24, 27), recognized rostral cerebral artery while Schwarze and Schroder (1970) (30), Nickel

(1977) (2), King and McLelland (1981) (31) did not cite the existence of the rostral cerebral artery in domestic birds. In the sparrowhawk, the left rostral cerebral artery was duplicated in all of the samples while the right rostral cerebral artery was a single branch in six of the all samples. However, in the ostrich (26), on the left it was single in 96.7% of the samples.

In summary, in this study the vascular construction and ramification of the brain base arteries in the sparrowhawk were determined. It is hoped that the existing outcomes will ease understanding of the phylogenetic relationships and morphological similarities among different bird species. In addition, we believe that this information will provide particular anatomical data regarding the sparrowhawk.

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