Brain stem arteries in *Canis familiaris* - implications in experimental procedures

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Abstract

Canis familiaris is widely used as an experimental model, namely in the study of vascular lesions in the region of the vertebro-basilar arterial system. Although there are some works published on the normal pattern of the arteries that supply the brain stem in this species, most studies were obtained from relatively small series, and scant information exists regarding the variations of the arteries of this region. To contribute to a better understanding of brain stem arteries in dog, we injected coloured latex in 25 adult mongrel dogs. The brain stems were removed and their superficial vessels carefully analysed under a stereotaxic microscope. Then, the brainstems were cut in 2 mm thick slices, and turned diaphanous, which allowed the study of their perforating arteries. All the arteries to the brainstem derived from the vertebral, basilar and caudal communicating arteries. Variations were found in the number of pontine arteries, in the different extent to which perforating arteries penetrated in the different portions of the brainstem, and in the morphology of the basilar artery. Overall, the general pattern of vascularisation is similar in dogs and in humans, with the important exceptions of the origin of the caudal cerebral artery and the rostral cerebellar artery, and the relatively larger contribution of the vertebro-basilar system to the brain blood supply in *Canis familiaris*. We conclude that, from an anatomical standpoint alone, the dog seems to be an adequate model for experimental procedures involving the arteries that supply the brainstem.

Keywords: brain stem, arteries, *Canis familiaris,* dog, experimental procedures.

1 Introduction

Seldom has an animal species been so frequently used as a model for understanding the pathophysiology and treatment of particular diseases as the *Canis familiaris* (common dog) is used today. In fact, each day, a myriad of experiments is conducted in dogs all over the world, resulting in the progress not only of veterinary sciences, but also in tremendous gains for medicine as a whole. In particular, recently, canine studies on subarachnoid hemorrhage (KATUSIĆ, MILDE, COSENTINO et al., 1993; KIMURA, SASAKI, MEGURO et al., 2002; MIZUNO, HAMADA, KAI et al., 2003a; 2003b; MORI, NAGATA, TOWN et al., 2001; MORI, ASANO, NAGATA et al., 1997; MUHONEN, OOBOSHI, WELSH et al., 1997; NAGATA, SASAKI, MORI et al., 1996; ORZ, TSUJI, AOKI et al., 1998; ZUBKOV, TIBBS, AOKI et al., 2000; ZUBKOV, TIBBS, CLOWER et al., 2002), new surgical techniques to access tumors of the posterior fossa (KLOPP, SIMPSON, SORJONEN et al., 2000), pathophysiological events in the compression of the cochlear nerve (HATAYAMA, SEKIYA, SUZUKI et al., 1999), hindbrain ischemia and reperfusion (GUO, LIAO, PRESTON et al., 1995; KOBAYASHI, IDE, KABUTO et al., 1996), just to name a few, have merited great attention and consensual applause by the scientific community. Useful as they are, all the studies mentioned above are highly dependent on a sound knowledge of both the normal pattern of distribution of the arteries that supply the brain stem in this species and their variations and also on the degree of homology between these pattern and human's. Only then will scientists start to appreciate to what extent may the results obtained in canine models be transferred to humans.

Although there are excellent works published on the arteries that supply dog's brain stem (ANDERSON and KUBICEK, 1971; BAPTISTA, 1922; GILLILAN, 1976; MAJEWSKA-MICHALSKA, 1998; TORRE and NETSKY, 1960; TORRE, MITCHELL and NETSKY, 1962), most of the results were obtained from relatively small series, and scarce attention has been paid to the variations theses arteries can present. In this work, we will attempt to deepen the knowledge of this arterial territory, paying particular attention to the variations found. We will also make a brief comparison with the normal distribution of these vessels in the human species, and the implications that may result from the analogies and differences found, in terms of experimental procedures.

2 Material and methods

Twenty five adult mongrel dogs were obtained from Lisbon's city kennel. The dogs were killed, after being sedated with pentobarbital, with an injection of a solution containing 10% formol in one of the femoral arteries. Shortly after, a median thoracotomy was performed, and the as-

cending aorta was catheterized proximally to the brachiocephalic trunk. A small incision was made in the lateral flank of the cranial vena cava. Then, the aorta was perfused with warm saline (approximately 37 °C) until the blood drained by the severed vena cava was replaced by saline. Next, a solution containing a 60 °C suspension of barium sulphate (Micropaque® - Nicholas Lab.), latex, and red pigment (Super Tintolac® - Robialac) was injected cranially through the catheter inserted in the aorta, according to the technique used in our department (FREIRE-DE-ANDRADE, 1983; PAIS, 1995). The injection was stopped when the red solution was seen emerging from the cranial vena cava. After the injection was completed, the cranial vena cava and aorta were closed with suture line. The *Cisterna magna* was accessed through a dorsal incision in the cervical region and a solution containing 10% formol was injected in the subarachnoid space, in order to better preserve the central nervous system. The specimen was kept in a refrigerator at a temperature of 4 °C for about 24 hours. Then, the cervical portion of the vertebral column and head were removed *en bloc*, and kept in a solution of formol 10% for a period of at least two weeks, allowing structures to become definitely fixed. Subsequently, all the specimens were carefully dissected under a stereotaxic microscope (Carl Zeiss®), allowing the detailed registry of all the arteries that supplied the brain stem and their superficial distribution. Finally, the brain stem was divided into 2 mm thick sections under a microtome and the ordered segments were studied under a binocular magnifying glass (Carl Zeiss®), after being made diaphanous by the technique currently used in our department (PAIS, 1995). These diaphanous segments allowed the study of the brain stem perforating arteries.

3 Results

In all the specimens studied, all the arteries that supplied the brain stem are derived directly or indirectly from the vertebral arteries (v.a.), from the basilar artery (b.a.), which resulted from the cranial convergence of both v.a., and from the two terminal branches of the b.a., which are named caudal communicant arteries (c.c.a.) in *Canis familiaris* (Figure 1). From the v.a., b.a., and c.c.a. three groups of arteries are formed: paramedian arteries (p.a.); short circumferential arteries (s.c.a.), and long circumferential arteries (l.c.a.) (Figure 2).

The p.a. originate from the dorsal flank of v.a., b.a., and c.c.a. (Figure 3), and have a variable length through the median portion of the brain stem. The s.c.a. have a larger caliber and length, supplying the ventral and lateral portions of the corresponding portion of the brain stem. Finally, the l.c.a., have an even larger caliber and length and irrigate not only the ventral and lateral portion of the brainstem, but also its dorsal portion, and the cerebellum.

At the level of the midbrain, the p.a. originate both from the distal portion of the b.a., and from the proximal part of the c.c.a.. These arteries, whose average number is 3,4 ± 0,4, perforate the ventral two thirds of the brainstem (Figure 3). The s.c.a. supply the ventral and lateral portions of the cerebral peduncles, being their average number 2,3 ± 0,8. The l.c.a. of the midbrain consist of the rostral cerebellar artery, caudal cerebral artery, and the caudal choroid artery. The rostral cerebellar artery derives from the c.c.a. in all cases.

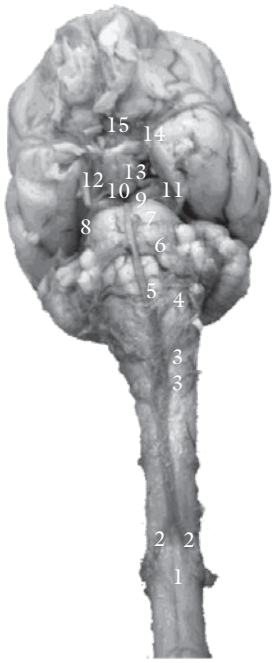

Figure 1. Photograph of the ventral surface of a dog's brain. This photograph illustrates the most frequently encountered pattern of the superficial arteries of the brain stem, and a few arteries of the brain base in *Canis familiaris*. 1 - ventral spinal artery; 2 - vertebral artery; 3 - short circunferential arteries of the medulla oblongata; 4 - caudal cerebellar artery; 5 - basilar artery; 6 - medial cebellar artery; 7 - short circunferential arteries of the pons; 8 - rostral cerebellar artery; 9 - mesencephalic artery (proximal portion of the caudal communicating artery); 10 - caudomedial branches of the caudal communicating artery; 11 - caudal cerebral artery; 12 - distal portion of the caudal communicating artery; 13 - hypophisary arteries; 14 - middle cerebral artery; and 15 - common artery of *corpus callosum*.

The caudal cerebral artery is a collateral branch of the c.c.a., and the caudal choroid artery is a branch from caudal cerebral artery. The s.c.a. and the l.c.a. originate a variable number of perforating branches in their course. These perforating branches, differently from the p.a., rarely go beyond one fourth of the thickness of the midbrain.

In the pontine region, the p.a. originate from the dorsal flank of the b.a.. These arteries, whose average number was 6,0 ± 1,4, supplied the ventral two thirds of the pons. The s.c.a., often called pontine arteries (average number 3,0 ± 1,6), provided branches to the ventral and lateral portions of this part of the brain stem. The l.c.a., at this level, are represented by the rostral cerebellar artery and by the middle cerebellar artery, that run along the ventral and lateral aspects of the pons, reaching the cerebellum and giving off numerous perforating branches to the surrounding structures.

The morphology of the arteries of this portion of the brain stem was particularly variable. In 80% of cases, the b.a. run along an almost straight line, whereas in the remaining cases it was markedly flexuous. The number of pontine arteries was also highly variable, ranging from two to seven on each side.

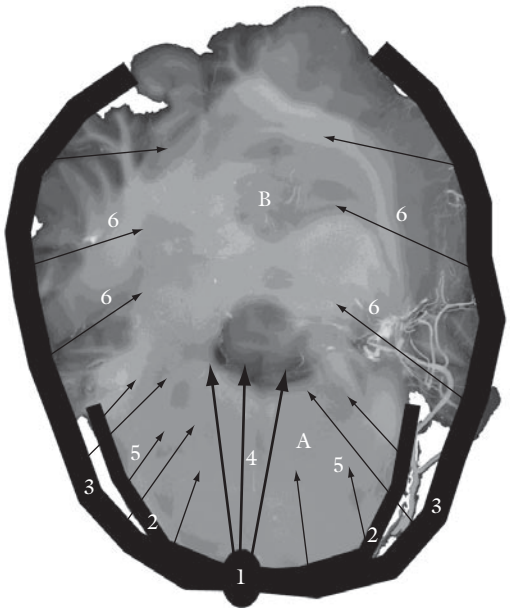

Figure 2. Transversal section of a dog's brain stem through the pons and cerebellum. A schematic representation of the basic organization of the arteries that supply the brain stem in *Canis familiaris* is presented. A - pons; B - cerebellum; 1 - basilar artery; 2 - short circumferential artery; 3 - long circumferential artery; 4 - paramedian arteries; 5 - perforating arteries originating from the short circumferential arteries; and 6 - perforating arteries from the long circumferential arteries.

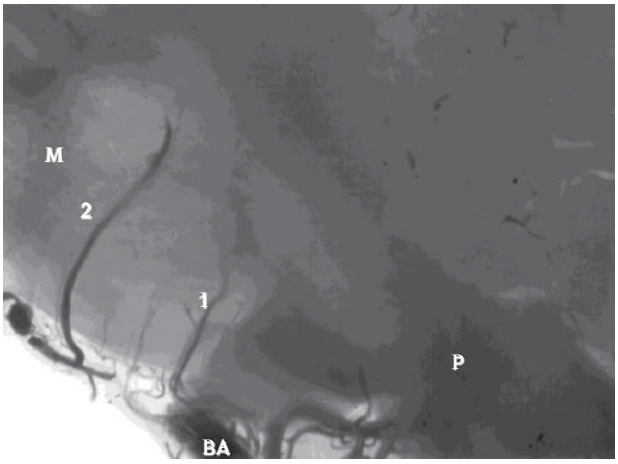

Figure 3. Photograph of a sagital section through the midbrain (M) and pons (P) of a specimen of *Canis familiaris*, in which several paramedian arteries of the midbrain can be seen. BA - basilar artery; 1 - paramedian branch originating from the distal portion of the basilar artery; and 2 - paramedian branch originating rostrally to the level of the basilar artery from the caudal communicating arteries (not shown in the photograph).

At the level of the medulla oblongata, the p.a. were, on average 5 ± 1,3, originating from the v.a., proximal portion of the b.a., and from the spinal ventral artery (v.s.a.). The v.s.a. could result from the reunion of two branches, each originating in the vertebral artery on the same side, from the point were the two vertebral arteries reunite to originate the b.a., or from only one of the vertebral arteries. Similarly to what happens in the two cranial levels of the brain stem, in the medulla oblongata the p.a. also supply the ventral two thirds of this region. The s.c.a., which ranged in number from 4 to 8 on each side, being their average number 4,3 ± 2,3, irrigated the ventral and lateral aspects of the medulla oblongata. The l.c.a. are represented, at this level, by the caudal cerebellar arteries that provided several perforating branches to the ventral and lateral portions of the medulla oblongata in its path to the caudal surface of the cerebellum. The perforating branches originating from this artery travel deeper within the medulla oblongata, often reaching between one third and one half of its thickness.

Finally, in all the specimens studied, we verified that most of the dog's arterial supply to the brain was dependent on the arteries that provided the brain stem, i.e., there appears to be a dominance of the vertebro-basilar circulation in this species, being the carotid circulation relatively less important.

4 Conclusion

Our results do not show substantial differences from the ones previously reported (ANDERSON and KUBICEK, 1971; BAPTISTA, 1922; GILLILAN, 1976; MAJEWSKA-MICHALSKA, 1998; TORRE and NETSKY, 1960; TORRE, MITCHELL and NETSKY, 1962). However, we found several variations in the dog's vertebro-basilar system that have been widely neglected in the bibliographic review we performed. Among these variations, we would like to highlight the variable number of s.c.a. in the pons region, the different extent to which the perforating branches penetrate in the different portions of the brainstem, and the degree of flexuosity of the b.a.. We believe that the knowledge of these normal variants may enhance the planning, execution, and interpretation of experimental procedures involving dog's vertebro-basilar circulation. Interindividual variations in b.a.'s morphology and the number of pontine arteries, may affect the results obtained in different specimens of *Canis familiaris* while performing reperfusion of the b.a. or one of its branches, via percutaneous transluminal angioplasty, for example.

Comparing the results obtained with those commonly described in the human species (NOLTE, 2002; SNELL, 2001; STOPFORD, 1917), we don't find dramatic differences in the general pattern of distribution of brain stem arteries, which probably confirms that, from an anatomical standpoint, *Canis familiaris* is adequate to simulate diseases of the vertebro-basilar arterial system in humans. However, some differences exist that should be taken into consideration, namely the fact that the caudal cerebral artery derives from the c.c.a. in the dog, whereas in humans it usually results from the bifurcation of the distal part of the b.a., and also that the rostral cerebellar artery originates from the c.c.a. in dogs, and from either the posterior communicating artery or from the terminal portion of the basilar artery in humans.

Another prominent difference between these two species is that, as other have stated (BAPTISTA, 1922; MAJEWSKA-MICHALSKA, 1998; TORRE and NETSKY,

1960; TORRE, MITCHELL and NETSKY, 1962), and as we could confirm, in *Canis familiaris* there is a clear predominance of the vertebro-basilar system in the arterial supply to the brain, while in the human species the dominant system is that of the internal carotid arteries. This important difference between the two species should always be born in mind when using dog as an experimental model.

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