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Anatomical study on the spinal arteries in the domestic cat (*Felis domesticus*)

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A B S T R A C T

To study the normal distribution of the arteries that supply the spinal cord of the cat, a colored latex solution was injected in the aorta of ten adult cats. The specimens were dissected to expose the spinal arteries in this species. The main arterial supplments of the spinal cord were the ventral spinal and dorsal spinal arteries. These arteries along their courses received several radicular arteries that arose from the vertebral, dorsal intercostal and lumbar arteries. Comparing the results obtained with those commonly described in humans, it is clear that the domestic cat shows a great similarity in most respects. However, marked variability of the spinal arteries arising from segmental arteries, the origin of the ventral spinal artery and the origin and presence of the Adamkiewicz artery were recorded. Overall, the data show that, from an anatomical standpoint, the cat seems to be a good model for spinal cord ischemia in humans.

Key words: Anatomy-Spinal arteries -Domestic cat.

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1. INTRODUCTION

Gillilan (1958) stated that Adamkiewicz carried outand published in 1881and 1882 the first extensivestudy on the blood vessels of the spinal cord, and thathis workand that of Kadyi (1889) were the only sources of accurate,detailed information and basic terminology on thissubject up until the late 1930s. Recently, the domestic cat has been broadly used as an experimental model for spinal cord disease. Therefore, the significance of a thorough understanding of the arterial supply to the spinal cord of Canis familiaris is of indisputable importance. Although several works have been published concerning spinal cord arteries in dogs (Anderson and Kubicek, 1971; Caulkins et al.,1989). The number of specimens analyzed in each study has usually been small, and not enough attention has been paid to the variability of these arteries. The enormous variability of the arteries that supply the spinal cord has been unmistakably demonstrated in several species, being probably more profusely documented in humans (Alleyne et al., 1998; Kawaharada et al., 2004; Koshino et al., 1999; Valleé and Spelle., 2002; Malikov, et al., 2002; Nijenhuis et al., 2004; Bosmia et al 2015).

The clinical importance of anatomic knowledge of this region lies in planning for endovascular surgery procedures on the aorta, in order to minimize the risk of ischemia, avoiding unnecessary occlusion of the spinal blood supply.

2. MATERIALS AND METHODS

Ten adult domestic cats were used in the study. The cats were sedated with pentobarbital before an injection of a solution containing 10% formol was injected in one of the femoral arteries. Shortly after sacrifice, a median thoracotomy was performed, and the ascending aorta was catheterized close to the brachiocephalic trunk. A smallincision was made in the lateral flank of the cranial vena cava. Then, the aorta was perfused with warm saline until the blood drained by the severed vena cava was replaced by saline. Next, a solution of red colored latex solution with Rotring ink was injected cranially through the catheter inserted in the aorta. The injection was stoppedwhen the red solution was seen emerging from the cranial vena cava. After the injection was completed, the cranial vena cava and aorta were ligated. A solution containing 10% formalin was injected into 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, In six specimens, the vertebral column and head were removed and kept in a solution of formalin 10% for a period of at least two weeks, allowing structures to become definitely fixed, then carefully dissected under a dissecting microscope, allowing the detailed registry of all the arteries that supplied the spinal cord and their superficial distribution (Pais et al.,2007),while in the remaining four specimens the extravertebral vessels were dissected to identify the origin of the segmental arteries devoted to vascularize the spinal cord. The nominculature used were adopted according to the Nomina Anatomica Veterinaria (2005).

3. RESULTS

The main arterial supplments to the spinal cord was achieved through three main sources; the vertebral, dorsal intercostal and lumbar arteries. These arteries detached a series of segmental arrteries in the vicinity of the intervertebrl foramina where the spinal nerves emerge from the vertebral canal. Each of these segmental arteries gave rise to a larger spinal radicular branch and a much smaller radicular branch. The former branchentered thevertebral canal through the corresponding intervertebral foramen and soon divided into a ventral and a dorsal radicular arteries which reinforce the ventral spinal and dorsal spinal arteries respectively. On the other hand, the small radicular branch was ramified in the vicinity of the nerve roots of the corresponding spinal nerve as well as the adjoining portion of the spinal cord.

The spinal cord receives blood from three longitudinal trunks: an unpaired ventral spinal artery and a pair of lateral dorsal spinal arteries and another pair of medial dorsal spinal arteries.

3.1. Spinalis ventralis

The ventral spinal artery (Fig. 1/5, 2, /1) was represented by a thin unpaired vessel extending along the ventral median fissure of the spinal cord from its point of origin up to the caudal end of the spinal cord near the cauda equina, showing adiversity of origin. The most common pattern of origin (7 specimens) resulted from the unionof two descending rami (Fig.1/4) each coming from the medial flank of the vertebral artery on the same side where the two vertebral arteries converge to form the basilar artery (Fig.1/3). In the remaining three specimens it arose independently from either the right vertebral artery (two specimens) or from the left one (one specimen). The ventral spinal arterythroughout its course was reinforced by a series of radicular arteries. *in the cervical region*, the ventral spinal arterywas reinforced on either side by five (4 specimens) or six (six specimens) ventral radicular arteries which erupted from the segmental branches of both vertebral arteries. *In the thoracic region* it continued its course caudally and reinforced by eight (six specimens), nine (three specimens) or ten (one specimens) ventral radicular arteries arising from the segmental arteries of the dorsal intercostals arteries. *In the lumbar region* of the spinal cord the ventral spinal artery received seven ventral radicular arteries arising from the corresponding segmental arteries of the lumbar arteries

3.2. Spinalis dorsalis lateralis

The lateral dorsal spinal arteries (Fig. 3/1) were represented by pair discontinuous vessels that extended along the dorso-lateral aspect of the spinal cord continued on the ventral surface of the dorsal nerve roots. Along its course it was reinforced by the anastomosis established between the R. cranialis and R. caudalis of the successive dorsal radicular arteries. However, in three of the examined specimens these vessels joined the contralateral vertebral artery and in another two specimens it joined the caudal cerebellar artery.

In the thoracolumbar region, the dorsal medial spinal arteries (Fig. 3/2) arose as delicate intermittent vessels arising from the lateral ones and extended along the dorsolateral fissures.

Along their course, the ventral and dorsal spinal arteries were profusely anastomosed by horizontal and oblique vessels forming an irregular arterial network often called spinal arterial ring. This network is denser in the vicinity of the cervical and lumbar portion of the spinal medulla.

At the level of each intervertebral foramen, spinal arterial ring was frequently reinforced by spinal branches of arteries outside the vertebral column through the ventral and dorsal radicular arteries that accompany the homonymous roots of the spinal nerves.

3.3. Radiculares

The radicular arteries are ventral and dorsal groups which gave reinforcement for the ventral and dorsal spinal arteries respectively. The total number for each group is ranged between 20-23 pairs of vessels. They arise from the segmental arteries of the vertebral artery in the cervical region and from the dorsal intercostal and lumbar arteries in the thoracolumbar region.

In the cervical region, there are 5-6 pairs, originated directly from the segmental arteries of vertebral arteries during their course in the vertebral canal. Each radicular artery passed through its corresponding intervertebral foramen then divided into a dorsal and a ventral radicular artery that reinforce the ventral spinal artery and the dorsal spinal arteries. Each ventral radicular artery (Fig.2/2, 3) bifurcated into a Ramus cranialis (Fig.2/4) and a Ramus caudalis (Fig.2/5) which united to form the diamond-shaped anastomosis.

In the thoraco-Lumbar region, there were 15-17 pairs, arising from the dorsal intercostal arteries as well as the lumbar arteries.They passed through their corresponding intervertebral foramina and similarly behave like those found in the cervical region.

There was a large ventral radicular spinal artery on the left side at the level of the fourth lumbar vertebra which was constantly present in all examined cats. This artery could be favorably matched with the so called great ventral medullary artery or Adamkiewicz artery.

The Adamkiewicz artery (Fig. 4/1) supplied the ventral aspect of the caudal portion of the spinal cord. On reaching the ventral median fissure, the Adamkiewicz artery was divided into two branches cranial and caudal. The cranial branch (Fig. 4/2) reinforced the caudal end of the ventral spinal artery while the caudal branch (Fig. 4/3) continued the course of the ventral spinal artery through the caudal portion of the spinal cord. It was noticed absence of any radicular branches of the sacral segmental arteries as the great radicular arteries may compensating their deficient in this region.

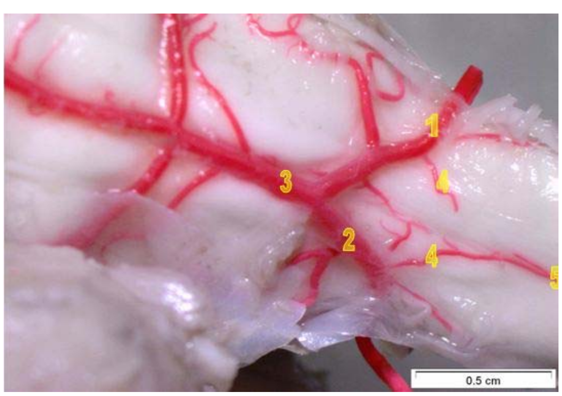

Fig (1): A photograph showing the formation of the basilar artery as well as several descending branches that joined and formed ventral spinal artery. 1) A. vertebralissinsitra, 2) A. vertebralisdextra, 3) A. basilaris, 4) Rr. descendens, 5) A. spinalis ventralis.

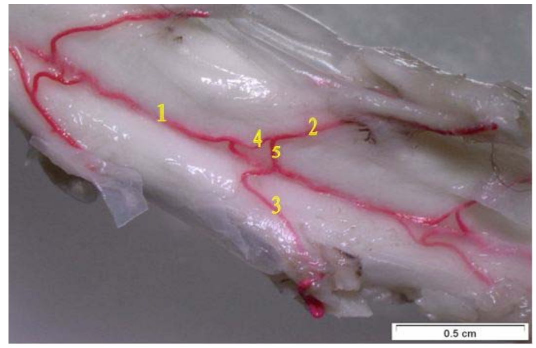

Fig (2): A photograph showing diamond shape anastomosis (ventral view). 1)A. spinalis ventralis, 2)A. Radicular ventralis sinsitra, 3)A. Radicular ventralisdextra, 4)R. cranialis, 5)R. caudalis

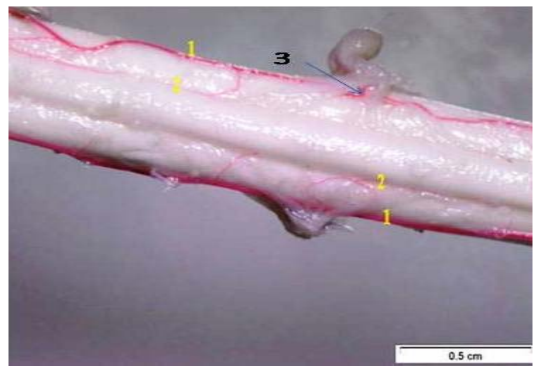

Fig (3): A photograph showing dorsal aspect of lumber spinal cord. 1) A.spinalis dorsalis lateralis, 2) A.spinalis dorsalis medialis, 3) A.radicularis dorsalis.

Fig (3): A photograph showing the fourth lumber radicular artery (ventral view). 1) A.Radicularis magna ventralis (Adamkiewicz artery), 2) R.cranialis, 3) R.caudalis.

4. DISCUSSION

The present work revealed that arterial blood supply of the spinal cord were derived from ventral spinal artery, dorsal spinal arteries , which were reinforced along their course by ventral and dorsal radicular arteries respectively a result which simulates that have been accounted by Sisson and Grossman (1969) and Wilkens and Munster (1981)in domestic animals, Bradshaw(1958) in cat, Wissdorf(1970) and Patsukova (1973) in pig, Jellenger (1966) and kenawey (1985) and Mazensky et al., (2009) in rabbit and Martirosyan et al.,(2011) and Bosmia et al., (2015) in human. In cat, the presence of one single ventral spinal artery and two dorsal spinal arteries on either sides of the dorsal surface of the spinal cord was also reported by Bradshaw (1958) and Chambers et al. (1972) in cat. However, in canine Paiset al., (2007) recorded two dorsal medial spinal arteries a result which is only observed in the lumbar region in the cat.

The current investigation revealed the origin of the ventral spinal artery from the unionof two descending rami each coming from the medial flank of the vertebral artery on the same side where the two vertebral arteries converge to form the basilar artery as also mentioned in human (Heimer, 1995; Nolte, 2002). On the other hand in domestic animals Goshal (1975) gave its origin from the cerebrospinal branch of the occipital artery. It is to add that, Nanda (1975) mentioned that the ventral spinal artery was considered as representing the spinal continuation of the basilar artery in domestic animals. Woollam and Millen (1955), Noeske (1958) in man and Wissdorf (1970) in pig as well as Tveten (1976) in rathad declared that the ventral spinal artery was represented by a midline chain of anastomoses which run the whole length of the cord. However, the origin of the ventral spinal artery from one vertebral artery, either right or left observed in some of the examined specimens in cat was also recorded in canine by Pais et al., (2007) who mentioned the presence of two ventral spinal arteries each arose from the vertebral artery of the same side and then it might be united to form a single vessel. The latter authors also added that this should be taken into account when inducing ischemia of the upper portion of the spinal cord in dogs in experimental settings.

In agreement with Bradshaw (1958) and Chambers et al. (1972) in cat and Kenawey (1985) in rabbit the dorsal spinal arteries were in the form of paired irregular vessel formed by the anastomoses established between the R.cranialis and R.caudalis of the successive dorsal radicular arteries. Champers et al. (1972) in cat, Tveten (1976) in rat and Abd el-Ghany (1995) in goat revealed that the paired dorsal spinal arteries were derived from the vertebral arteries on a level with the first cervical spinal nerve root, extending caudally along the whole length of the dorsolateral aspect of the spinal cord. However in three of our examined specimens these vessels joined the contralateral vertebral artery and in another two specimens it joined the caudal cerebellar artery.

According the present study it was found that the ventral and dorsal spinal arteries are profusely anastomosed by horizontal and oblique vessels forming an irregular arterial network often called spinal arterial ring. This network is denser in the vicinity of the cervical and lumbar portion of the spinal medulla. This disposition was also described in humans (Snell, 2001)., and may justify that, in situations of severe hypotension, the human thoracic region is more susceptible to ischemia

In viewing of the present investigation, the radicular arteries are ventral and dorsal groups which gave reinforcement for the ventral and dorsal spinal arteries respectively. The total number for each group is ranged between 20-23 pairs of vessels. They arose from the segmental arteries of the vertebral artery in the cervical region and from the dorsal intercostal and lumbar arteries in the thoracolumbar region.In this respect these vessels were 18 ventral and 29 dorsal branches in goat (Abd El-ghany, 1995) or from 17-20 in rabbit (Kenawey, 1985).

In cat, a large ventral radicular artery on the left side at the `level of the fourth lumbar vertebra which was observed in all examined specimens and was responsible for the arterial supply the ventral aspect of the caudal portion of the spinal cord. This vessel could be favorably matched with the so called great ventral medullary artery or Adamkiewicz artery recorded in canine by Pais et al., (2007). The latter authors mentioned its origin from the fifth lumbar artery. In human Amato and Stolf (2015) described the Adamkiewicz artery as a dominant one of the anterior radicular arteries in terms of caliber and is known as the great anterior radicular artery. Moreover, Crosby and Gillilian (1962) stated that Often, when the artery of Adamkiewicz arises from higher levels, between T5and T8, it is supplemented by an additional conal artery, which emanated from the internal iliac artery; this conal artery is referred to as the Desproges Gotteron artery which was usually located between L2 and L5 (Novy et al., 2006).

A study of acute spinal cord lesions in monkeys induced by occlusion of the anterior medullary arteries by Yoss (1950) showed that pathologic results correlated directly with the size of the blood vessels involved. Occlusion of the artery of Adamkiewicz results in severe damage to the anterolateral two thirds of the spinal cord at the level of entrance of this artery into the spinal cord and for a distance above and below.

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