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ARE THE VARIATIONS OF THE VASCULAR SYSTEM IN NEUROLOGY UNDERESTIMATED?

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ABSTRACT

The spinal cord issues affect dogs and cats very commonly. The right diagnostics, therapy, and patient's managements are challenging for almost all veterinarians. There exist many vascular anomalies such as: the vertebral arteries ectasia, hypoplasia and subclavian steal syndrome. These anomalies affect the patient's neurological status directly. The modern diagnostic approaches (Computed Tomography [CT], and Magnetic Resonance Imaging [MRI]) help with the diagnosis of the vascular abnormalities of the spinal cord and various other vascular anomalies. The cervical part of the spinal cord is supplied with the spinal branches from the vertebral arteries. The vertebral arteries as the first branches arise separately from the subclavian artery and they exit the thoracic aperture and enter into the transverse foramen of the sixth cervical vertebra. The arterial system of dogs was studied in 14 dogs (carcasses), the average age of which was 7 years. The carcasses were divided into two groups: 11 dogs were studied by the corrosion casting method (Duracryl Plus) and 3 dogs were studied by contrast radiography (Urografin 76 %). We confirmed the standard origin and course of the left vertebral for all but one case. The right vertebral artery originated as an independent branch in 57.14 % of the cases; in the rest of them, we reported on the variability in origin and formation of inconstant branches. The formation of anastomoses was reported also. Our work contributed new information about the thoracic and cervical arterial system in dogs.

Key words: arteries; corrosion casting; dog; neurology; spinal cord; vertebral artery

INTRODUCTION

Vertebral arteries (VA), as the first branches of the subclavian arteries in dogs, are responsible for the cervical spinal cord blood supply. Vertebral arteries leave the thoracic cavity through the *apertura thoracis cranialis* and they enter into the transverse foramen of the 6th cervical vertebra between the scalene muscle and the *longus coli* muscle [15, 19]. VA provide: a blood supply for the spinal cord (*rr. spinales*, *a. spinalis ventralis*), caudal part of the brain, brainstem, meninges (*a. basilaris*), muscles, and skin (*rr. musculares*) of the neck [15]. The cervical spinal cord is supplied by the spinal branches of the vertebral arteries. These branches enter into the intervertebral foramina alongside the roots of spinal nerves and into the vertebral canal. They are then divided into the unpaired

ventral branch, and paired dorsolateral branches. The largest branch is the ventral spinal artery which runs in the ventral fissure of the spinal cord. The smaller dorsolateral branches run in the dorsolateral sulcus of the spinal cord near the dorsal roots of the spinal cord [8, 19].

Many spinal malformations do not produce overt neurologic dysfunction. It is the responsibility of the clinician to investigate and determine whether the malformation is an incidental finding or the underlying cause of a neurological clinical situation [21].

In the available anatomical books, possible variations of the vascular system are not described fairly, or they are characterised poorly [4, 8, 15, 19]. The variations of the vertebral arteries (origin, course and branching patterns) attract the same clinical interest in the humans as they do in the veterinary literature [11].

The purpose of this study is to describe the variations in the formation and course of the vertebral arteries and to contribute new knowledge about arterial system in dogs. The strong educational character of this paper is expressed by the original images and illustrations.

MATERIALS AND METHODS

We used carcasses of 14 mix-breed dogs for this study; the average age of the dogs was 7 years. Due to an incurable stage of their diseases or trauma the dogs were euthanized at the Small animal clinic of the University of Veterinary Medicine and Pharmacy in Košice based on the owners' request.

The intravenous drugs used for the euthanasia were as follows: premedication with sedatives Butorphanol 0.3 mg.kg^{-1} (Butomidor 10 mg.kg^{-1}, Richter Pharma AG, Austria) and Medetomidine 0.02 mg.kg^{-1} (Cepetor KH 1 mg.kg^{-1}, CP-Pharma Handelsgesellschaft GmbH, Germany). Then the general anaesthetic agent Propofol 2.0 mg.kg^{-1} (Propofol 2 mg.kg^{-1}, Fresenius Kabi GmbH, Germany) was used to provide deep anaesthesia, and finally Thiopental 1.0 g pro toto (Thiopental VUAB 1.0 g, VUAB Pharma a. s., Czech Republic) was administered.

Eleven carcasses were perfused with 0.9 % sodium chloride solution (Mikrochem Trade, s. r. o., Slovakia) with sodium citrate (Mikrochem Trade, s. r. o., Slovakia) through the ascending aorta after the humane euthanasia and acrylic self-curing dental resin Duracryl Plus (SpofaDental, a. s., Czech Republic) was administered through the ascending aorta after the perfusion. After polymerisation of the resin, maceration of the soft tissues was performed by a maceration unit (BM 1115, Gastrolux, s. r. o, Slovakia). Sodium hydroxide (Mikrochem Trade, s. r. o., Slovakia) at 2 % concentration was used as a maceration medium. The maceration process continued over two to four days at 70 °C. Finally, the macerated specimen was dried at a room temperature and inspected macroscopically and in some cases microscopically under a surgical microscope Carl Zeiss Movena S7 (Carl Zeiss AG, Germany).

The remaining three carcasses underwent a contrast arteriography of the subclavian arterial branches. The contrast agent sodium amidotrizoate (UROGRAFIN 76 %, Bayer AG, Germany) was administered through the descending aorta into both subclavian arteries. The radiographs were taken using the Gierth HF 200 (GIERTH X-Ray international GmbH, Germany), immediately after application of the contrast agent in ventrodorsal (VD) and laterolateral projections.

Ethical considerations

The owners of dogs agreed with the participation of the carcasses in this study.

RESULTS

In all investigated cases the left vertebral artery was the first separate branch from the left subclavian artery. The course of the left vertebral artery was standard; the vessel left the thoracic inlet in the cranio-dorsal direction and it entered into the transverse foramen of the sixth cervical vertebra anatomically (Fig. 1). Only in one case, the left vertebral artery did not enter into the transverse foramen of the sixth cervical vertebra and the course of this vessel was atypical, it entered into the fifth cervical vertebra (Fig. 5).

The right vertebral artery was a separated branch from the right subclavian artery in most of the dogs. In contrast, with the left vertebral artery, the right vertebral artery originated in very closed proximity with the costocervical trunk. The right vertebral artery originated anatomically at the same level, medially from the costocervical trunk. The lateralisation of the costocervical trunk was observed. The formation of the common trunk was observed in two

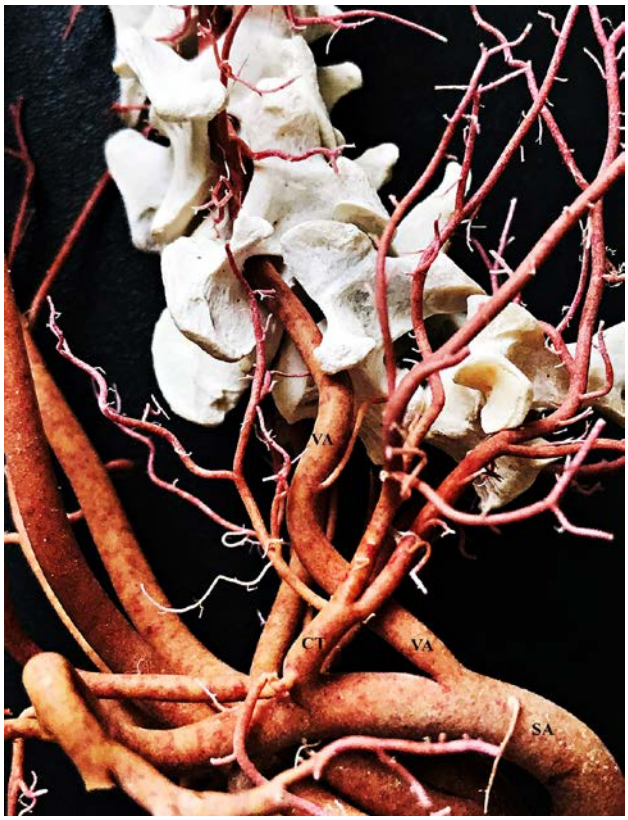


Fig. 1. The detailed view on the standard origin and course of the left vertebral artery and the left costocervical trunk
SA – subclavian artery; CT – costocervical trunk; VA – vertebral artery



Fig. 2. The formation and course of the right vertebral artery with communicating branch with the deep cervical artery
BT – brachiocephalic trunk; SA – subclavian artery; CT – costocervical trunk; DCA – deep cervical artery; VA – vertebral artery; CCA – common carotid artery; SCA – superficial cervical artery; AA – axillary artery

Table 1. Details of the course and formation of vertebral arteries

No.	Left vertebral artery	Right vertebral artery	Method
1	Standard course and formation	Very close contact with the costocervical trunk	CC
2	Standard course and formation	Standard course and formation	CC
3	Standard course and formation	Standard course and formation	CC
4	Standard course and formation	Standard course and common trunk with the costocervical trunk and communicant branch with the deep cervical artery	CC
5	Standard course and formation	Standard course, send out the deep cervical artery	CC
6	Standard course and formation	Standard course and formation	CC
7	Standard course and formation	Standard course and formation	CC
8	Standard course and formation	Standard course and formation	CC
9	Standard course and formation	Standard course and formation	CC
10*	Atypical course to the transverse foramen of C5	Very close contact with the costocervical trunk	CC
11	Standard course and formation	Standard course and formation	CC
12	Standard course and formation	Very close contact with the costocervical trunk	CS
13	Standard course and formation	Common trunk with the costocervical trunk	CS
14	Standard course and formation	Standard course and formation	CS

*—published by K o r i m et al. 2022; CC—corrosion casting; CS—contrast study; C5—fifth cervical vertebra

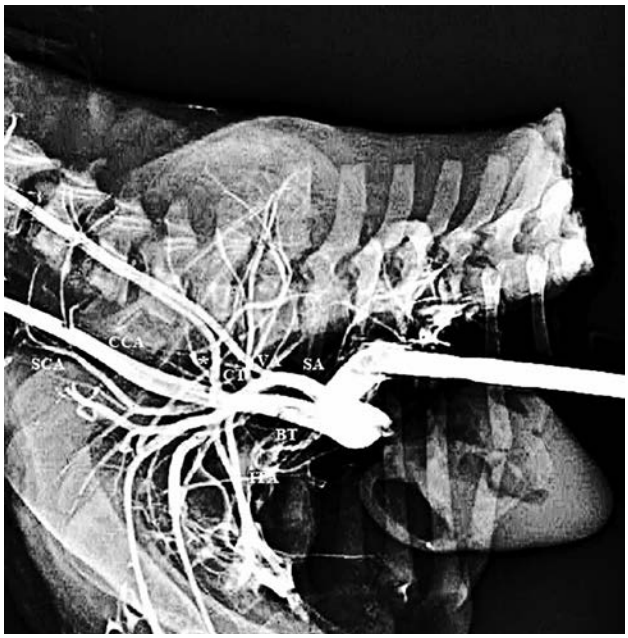


Fig. 3. Contrast arteriogram of the branches from subclavian arteries (laterolateral projection) – presence of the common trunk of the right vertebral artery and the right costocervical trunk
BT – brachiocephalic trunk; SA – subclavian artery; CT – costocervical trunk, VA – vertebral artery; CCA – common carotid artery; SCA – superficial cervical artery; ITA – internal thoracic artery; * – common trunk for origin of the right vertebral artery and the right costocervical trunk

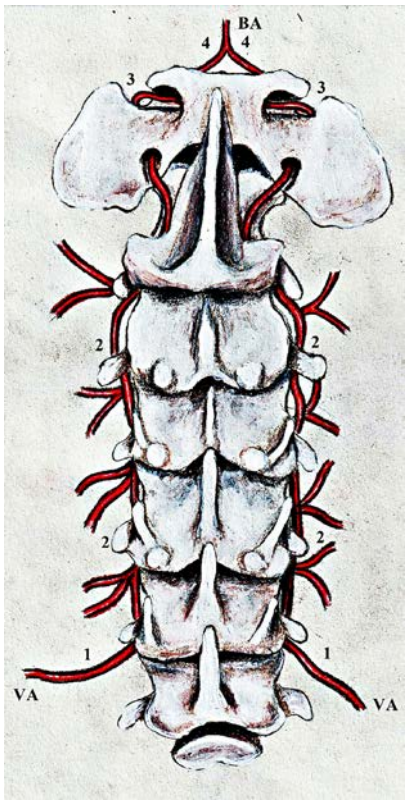


Fig. 4. The course and segmentation of the vertebral artery in dog (dorsal view)
VA – vertebral artery; BA – basilary artery; 1 – preforaminal part of the vertebral artery; 2 – foraminal/transversal part of the vertebral artery; 3 – atlantic/extradural part of the vertebral artery; 4 – intracranial/intradural part of the vertebral artery

dogs (14.29 %). The very close contact with the costocervical trunk was observed in three cases (21.43 %) (Fig. 3). However, the course of the right vertebral artery was normal and the artery entered the sixth cervical vertebra in all dogs. In one case (7.14 %), the right vertebral artery sent out the deep cervical artery. The communicating branch between the right vertebral artery and the deep cervical artery was observed in one dog (7.14 %) at the level between the first and the second thoracic vertebra (Fig. 2). The details of the course and formation of the vertebral arteries are described in Table 1.

We can divide the vertebral artery into the four segments:

1. Preforaminal or prevertebral segment which runs from the place of origin to the transverse foramen of the C6;
2. Foraminal or transverse segment which is in the transverse canal;
3. Atlantic or extradural part of the vertebral artery is at the level of the first cervical vertebra (atlas); and
4. The intracranial or intradural segment of the vertebral artery is represented by the formation of the basilary artery (Fig. 4).

DISCUSSION

The veterinary literature does not divide the vertebral artery into the segments [8, 16, 19]. We took the segmentation of the vertebral artery from a human anatomy [1, 11, 14], and this should also be used in veterinary medicine to characterize the lesions and their localisations more accurately.

The variability of the vertebral arteries at the place of origin was studied in laboratory animals and dogs. The course of both vertebral arteries was standard, and they entered into the sixth cervical vertebra and pierced the transverse foramen in all subjects studied [4, 5, 9, 12, 13, 15].

P o l s et al. [15] characterised the branching patterns to the I – scale in dogs. The pattern of branches from the subclavian arteries according to D a r a w i r o j et al. [4] in 58 mix-breed dogs were as follows: The vertebral artery was the first branch in the majority of the dogs. In some dogs, the vertebral artery originated in the proximity from the costocervical trunk and sometimes they formed the

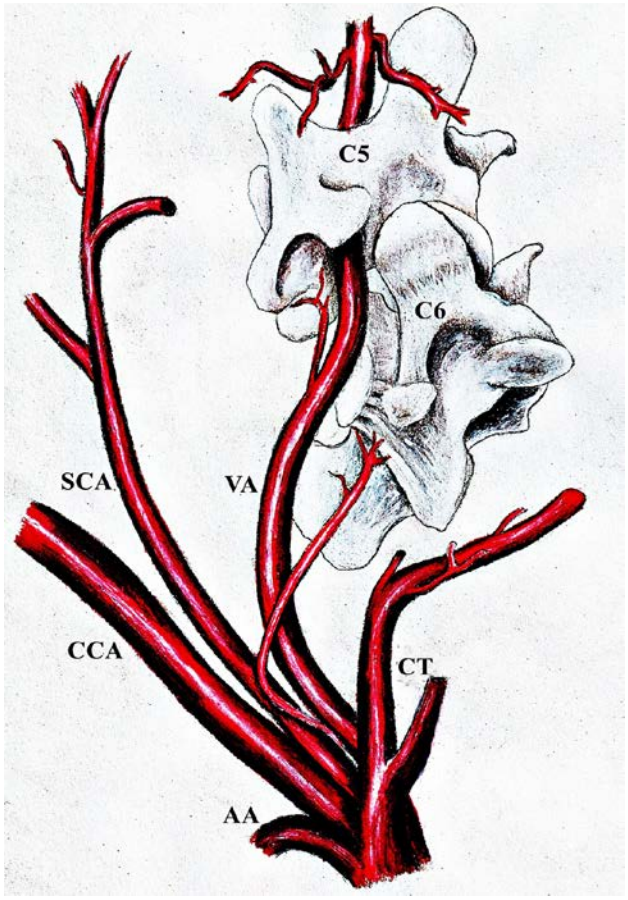


Fig. 5. The atypical course of the left vertebral artery with malformation of the sixth cervical vertebra. Scheme according to K o r i m et al. [7]

CT – costocervical trunk; VA – vertebral artery; CCA – common carotid artery; SCA – superficial cervical artery; AA – axillary artery; C5 – fifth cervical vertebra; C6 – sixth cervical vertebra

common trunk. In the minimum number of cases, the vertebral artery was the second branch from the subclavian artery. K ü r t ü l et al. [9] observed a standard formation and course of both vertebral arteries in dogs. A very rare case of an unilateral left asymmetry of the sixth cervical vertebra with atypical course of the left vertebral artery in the dog has been previously described [7].

The possible arrangements of the vertebral artery in the guinea pig was studied by F l e s a r o v a et al. [5]. The vertebral artery can be formed as an independent branch from the subclavian artery, but these authors found the common trunk with the dorsal scapular artery. In some cases, the vertebral artery was formed by fusion of two separate arteries. In rabbits, the origin of the vertebral artery is similar to that in the guinea pigs. In some cases, the vertebral artery originated directly from the aortic arch [12, 13].

The ectasias of vertebral arteries in dogs were described by B o z y n s k i et al. [3] and W e s t w o r t h et al. [20]. W e s t w o r t h et al. [20] described the dilatation of the vertebral arteries (especially the left vertebral artery) at the transverse foramen of the 6th cervical vertebra and ectasias of the radicular branches at the site of C5—C6 intervertebral disc space in a 3-year-old German short-haired pointer dog. The dog suffered tetraparesis and spinal ataxia with C6—T2 myelopathy. The anastomoses between vertebral arteries were observed at the ventral aspect of the vertebral canal at the C5—C6 intervertebral space. B o z y n s k i et al. [3] described the dilatation of both vertebral arteries between C4—C6 in a 4-year-old Catahoula Leopard dog. The clinical signs were the same as in the study of W e s t w o r t h et al. [20] and ectasia and tortuosity of the spinal branches of the vertebral arteries and the ventral spinal artery were described.

The subclavian steal syndrome (SSS) is defined as a hemodynamic phenomenon characterized by retrograde blood flow in the artery. Subclavian steal syndrome affects the vertebral artery mainly and it is asymptomatic in the majority of cases. The pathophysiology of SSS is described by occlusion of the vessel lumen or cumulation of atherosclerotic plaques (stenosis) which is the most common cause of the SSS in humans. The result of occlusion or stenosis is decreasing of the blood pressure leading to retrograde vertebral artery flow from the contralateral normal vessel by the basilary artery, circle of Willis or radicular branches. The redirection of the blood flow can lead to the cerebral ischemia. [6, 10, 17, 18]. On the other hand, SSS is extremely rare in dogs. There exist only a few cases describing the SSS in dogs [2, 18, 20]; SSS can be diagnosed by Doppler ultrasonography, contrast computed tomography and contrast magnetic resonance imaging [17, 20].

CONCLUSIONS

The findings of this study confirmed the slight variability of the vascular system of the cervical area in dogs. In all dogs, the left vertebral artery was the first branch from the left subclavian artery. The right vertebral artery reported higher variability. The importance of the arterial system (especially vertebral arteries) in veterinary neurology mainly during diagnostics has a key role and it can significantly influence the direction of therapy. However, the limitation of this study is a small sample of investigated subjects.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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