

Branching Pattern of Aortic Arch in the Korean Water Deer

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(Received 12 November 2007/Accepted 10 June 2008)

ABSTRACT. This study examined the branching pattern of the aortic arch and its major branches in Korean water deer (*Hydropotes inermis argyropus*, Heude, 1884). Silicone casts were taken from the vessels of 23 carcasses (male 14, female 9) with body weights ranging from 1.3–16.0 kg through a retrograde injection into the abdominal aorta. The findings were compared with those from other domestic ruminants. Only the brachiocephalic trunk (Bct) branched from the aortic arch in all carcasses. In 19 of the 23 cases, the Bct branched into the left subclavian artery (LSb), the left common carotid artery (LCc), and then trifurcated into the right common carotid artery (RCc), right costocervical trunk (RCct) and right subclavian artery (RSb). The subclavian artery (Sb) branched into the costocervical trunk (in left), internal thoracic artery (It), and superficial cervical artery (Sc) in that order, and continued as the axillary artery. Instead of separated carotid arteries, the bicarotid trunk from the Bct was observed in only three males and one female. Two of these males had different branching orders of the It and Sc from the Sb in one or both sides. The other male had a RCct from the RSb. The left costocervical trunk (LCct) arose from the LSb in all cases, and branched into the highest intercostal artery, the dorsal scapular artery, and the deep cervical arteries in that order, and continued as the vertebral artery. In 22 cases, the RCct branched directly from the Bct at the same point in which the RCc (or bicarotid trunk) and RSb separated. The artery branching pattern from the RCct was similar to that of the LCct. These results suggest that the Korean water deer has a Bct with different branching patterns from those of domestic ruminants.

KEY WORDS: aortic arch, branching pattern, Korean water deer.

J. Vet. Med. Sci. 70(10): 1051–1055, 2008

The aortic arch (Aa) is found between the ascending aorta and descending aorta from the cranial to the heart. One or more major arteries branch from the Aa with patterns differing according to the species of mammal [15]. The three major branches of the brachiocephalic trunk (Bct), left common carotid artery (LCc) and left subclavian artery (LSb), branch from the Aa in humans [4, 12, 20, 26], Chimpanzees [6], mice [23], rats [13, 19, 23], hamsters [23], monotremata and sloths [20]. However, the two branches of the Bct and LSb branch from the Aa in rabbits [1, 2], dogs and cats [11, 21], monkeys [5, 6], guinea pigs [22], pigs [10], and llamas [20]. In some species of Chiroptera, Edentata and Cetacea [20], it was reported that 2 trunks, the right brachiocephalic trunk and left brachiocephalic trunk, branch off from the Aa. The right brachiocephalic trunk is a common trunk of the right common carotid artery (RCc) and right subclavian artery (RSb). The left brachiocephalic trunk is a common trunk of the LCc and LSb. Domestic ruminants and horses show only one artery of the Bct branching off from the Aa [8, 9, 15, 17, 18, 20].

Depending on the types of Aa branching, two, three or four arteries of the LSb, LCc, RCc, and RSb in that order might branch from the Bct. The two arteries of the RCc and RSb branch off from the Bct in cases where three arteries of the Bct, LCc, LSb branch from the Aa. The three arteries of the LCc, RCc and RSb branch off from the Bct in cases

where two arteries of the Bct and LSb branch from the Aa. However, the LSb, LCc and RCc branch off from the Bct, which continues as the RSb, in cases where only one artery of the Bct branches from the Aa.

The branching order from the Bct might be different, and the LCc and RCc might have a common trunk. Cats and ungulates, such as pigs, domestic ruminants, and horses, generally have a bicarotid trunk (Bc), which is a common trunk of the LCc and RCc [8–11, 21, 24]. The length of the Bc may differ between species and be eventually divided into both common carotid arteries.

The arteries and their order of branching from the subclavian artery (Sb) differ according to species. Moreover, there are differences between the left and the right sides in the same animal [1, 2, 8–11, 17, 21, 24].

The Chinese water deer (*Hydropotes inermis*) belongs to the order Artiodactyla, family Cervidae, and has an adult body weight of 11–14 kg. Its characteristics are a preference for water, smaller than deer, no antler, four teats and tusks [7]. The tusks are well developed with a large 4.7 cm tusk found in adult males, which might be a characteristic for distinguishing gender [16]. These features suggest that the water deer is a prototype deer. There are two different subspecies, *H. inermis argyropus* and *H. inermis inermis* [3]. *H. inermis argyropus* live in the Korean peninsula, and *H. inermis inermis* live in the area of the Yangtze River in China and the England and France in Europe [3, 7]. The Chinese water deer in Europe were introduced from the China, not Korea, after the Opium War [3, 7]. In this study, the term of ‘Korean water deer’ was used to describe the dif-

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Table 1. List of the arteries and their abbreviations

Arteries	Abbreviations
aortic arch	Aa
brachiocephalic trunk	Bct
bicarotid trunk	Bc
common carotid artery	Cc
left common carotid artery	LCc
right common carotid artery	RCc
subclavian artery	Sb
left subclavian artery	LSb
right subclavian artery	RSb
internal thoracic artery	It
left internal thoracic artery	LIt
right internal thoracic artery	RIIt
superficial cervical artery	Sc
left superficial cervical artery	LSc
right superficial cervical artery	RSc
costocervical trunk	Cct
left costocervical trunk	LCct
right costocervical trunk	RCct
highest intercostal artery	Hi
dorsal scapular artery	Ds
deep cervical artery	Dc
vertebral artery	Vt
axillary artery	Ax

ference in the habitats of the two Chinese water deer subspecies.

There are few anatomical reports on the Korean water deer. Won [25] and Jung *et al.* [14] measured several skulls, and Lee [16] examined their lifestyle and differences in skull size and hair. However, there are no anatomical reports on the other structures in the Korean water deer.

This study examined a series of studies to determine the anatomical characteristics of the Korean water deer, and compared the major branches from the Aa and its branching patterns with those of other domestic ruminants.

MATERIALS AND METHODS

Twenty three Korean water deer (male 14, female 9), donated from Gangwon Laboratory Service Centre from February 2004 to September 2006, were examined. None of

the deer showed any deformities. Four carcasses had a body weight < 5 kg, six animals weighed 5–10 kg, the other thirteen Korean water deer weighed 10–16 kg (Table 2).

The costal cartilage was cut along a line connecting the intrachondral joints in both sides, and an incision line was extended to the inguinal region to open the thoracic and abdominal cavities. Silicone casts were made to confirm them after the dissection, and the branching patterns of the aortic arch and its major branches were examined. Commercial silicone (Lucky-Silicon Ind. Co. Ltd., Chungju, Korea) was infused retrogradely into the abdominal aorta after clearing the blood clots and washing the lumen of the vessels with water. After 24 hr, the casts were taken and photographed. Diagrams were also made to compare them with those of other domestic ruminants, which are described in references [9, 17].

RESULTS

The Aa in the Korean water deer branches at only one of the Bct. The first and second branches of the Bct are the LSb and LCc, respectively. The Bct then branches into three arteries, the RCc, right costocervical trunk (RCct), and RSb. This type was observed in nineteen (82.6%, 11 males and 8 females) of the twenty three Korean water deer (Fig. 1). Therefore, this type is considered to be typical of the species.

The following branching pattern from the LSb was observed: the left costocervical trunk (LCct), left internal thoracic artery (LIt), and left superficial cervical artery (LSc) in that order. After the LSc branched, the LSb continued as the left axillary artery (Ax). The RSb ramified the right internal thoracic artery (RIIt) and the right superficial cervical artery (RSc) in that order, and then continued as the right Ax (Fig. 1).

The LCct and RCct had a different ramification site, as described above. The LCct branched from the LSb, while the RCct was ramified from the Bct directly. However, the branching order of the arteries from the LCct and the RCct were the same i.e. the highest intercostal artery (Hi), dorsal scapular artery (Ds), and deep cervical artery (Dc) branched

Table 2. Gender and body weight of the 23 Korean water deer (*H. inermis argyropus*)

Serial number of the animal	Sex	Body weight (kg)	Serial number of the animal	Sex	Body weight (kg)
1	Male	1.3	13	Male	13.8
2*	Male	1.3	14	Male	14.0
3*	Male	1.8	15	Female	2.0
4	Male	5.8	16	Female	5.0
5	Male	6.9	17	Female	9.1
6	Male	7.8	18	Female	10.1
7*	Male	8.0	19	Female	14.4
8	Male	11.0	20	Female	14.7
9	Male	14.0	21	Female	16.0
10	Male	14.0	21	Female	16.0
11	Male	14.0	23*	Female	14.5
12	Male	12.0			

* The bicarotid trunk in these four animals branched from the brachiocephalic trunk.

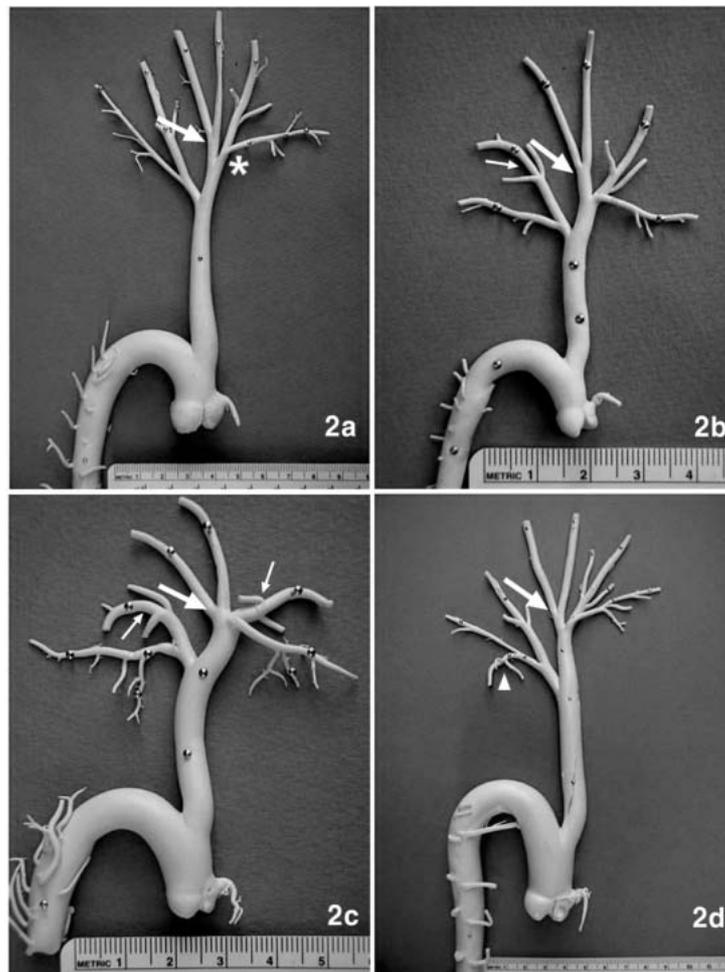


Fig. 2. Silicone casts showing four atypical branching patterns of the aortic arch and its major branches in the Korean water deer. Large arrows: bicarotid trunk, small arrows: the point where the internal thoracic artery and superficial cervical artery are ramified at the same level, asterisk in 2a; right costocervical trunk branched from the right subclavian artery, arrowhead: the point where the dorsal scapular artery branches from the highest intercostal artery. Dorsal view.

remodeling the aortic sac and its fusion with parts of the third and fourth aortic arches on both sides at the embryonic period [18]. During embryonic growth, the heart is moved to the caudal, and the Aa begins to remodel. At this time, the seventh dorsal intersegmental arteries for the distal part of the RSb or LSb move to the cranial. The degree of movement of the left for the LSb differs among domestic animals. There is a greater degree of movement in cattle and horses than in dogs and pigs. Hence, the LSb arises from the Bct directly [18].

The Korean water deer thorax has a similar shape to other ungulates but might differ in detail considering the dividing sites of the LCc. In addition, it is believed that the formation of the Bct is also similar in other domestic ruminants and horses but the formation of the Cc on both sides is different.

In this study, the animals' age ranged from young to

adults. Therefore, a modification of the branching pattern depending on growth was suspected. However, it was assumed from various reports that newborn animals would have the same branching pattern as adults. Gielecki *et al.* [12] reported that the formation of the arteries from the Aa is complete in the early embryonic stage, and that 80.6% of human fetuses aged between 14 to 30 weeks showed a normal pattern with the same variations in 19.6% compared with adults. Monnereau *et al.* [19] reported that 98% of 21-day old rat fetuses had the same branching pattern as adults.

The diameter and length of the Aa and its arteries are dependent on age [19]. Unfortunately, there was an insufficient number of the Korean water deer to make a proper comparison according to each growth period such as suckling, weaning, growth, sexual maturation and adulthood. Therefore, more study will be needed to examine the size

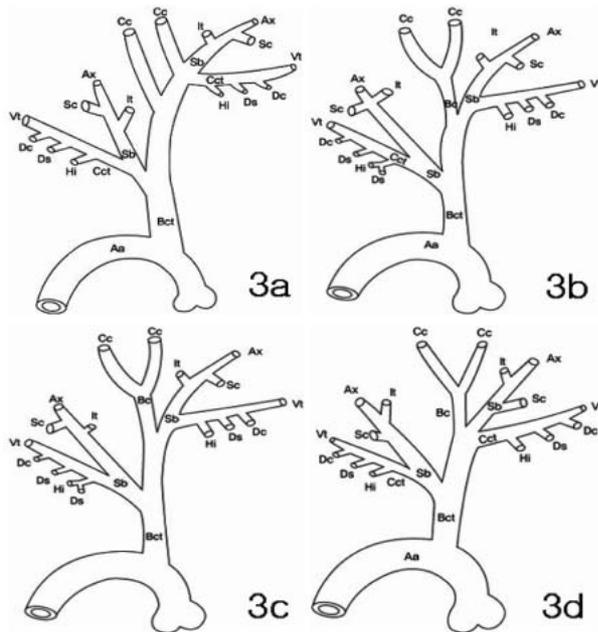


Fig. 3. Schematic diagram comparing the branching pattern of the aortic arch and its major branches in Korean water deer with those of other domestic hoofed animals. 3a; Korean water deer, 3b; cattle, 3c; sheep and goat, 3d; Korean native goat. Dorsal view. The abbreviations are the same as those shown in Fig. 1.

and the length of the Aa and its arteries as well as the distance between the arteries in Korean water deer.

ACKNOWLEDGEMENTS. This study was supported by grant No. (R01-2005-000-10369-0) from the Basic Research Program of Korea Science & Engineering Foundation and 2nd stage Brain Korea 21 Project and the Institute of Veterinary Science in Kangwon National University.

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