The branching of the aortic arch in the Eurasian bittern (*Botaurus stellaris*, Linnaeus 1758)

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ABSTRACT: This study was aimed at determining the vascular architecture of the aortic arch in the Eurasian bittern. For this purpose, the heart arteries of two bitterns were evaluated. The latex injection method was used to observe the branching of the aortic arch. Two brachiocephalic trunks were arising separately from the aortic arch and these arteries were giving to the common carotid and subclavian arteries. One of the thin branches arising from the subclavian artery was the sternoclavicular artery, which was in turn dividing into a sternal and a clavicular artery supplying the thoracic inlet and pectoral muscles. After the branching of the sternoclavicular artery, the axillary arteries were originating from the subclavian arteries. The thickest branch of the subclavian artery was the thoracic artery, which was dividing into internal and external thoracic arteries. Moreover, the brachiocephalic trunks were giving rise to the common carotid arteries and these were running cranially, giving rise to tracheosyringeal branches supplying the trachea and syrinx, thyroid artery, esophageal branches, artery of the comes nervi vagi and vertebral trunk. It is hoped that this study will enhance morphological data on exotic birds since the reports on species-specific vascular morphology in wild birds are insufficient and lacking in detail.

Keywords: aortic arch; arterial branching; bittern

In contrast to mammalians, two brachiocephalic trunks arise fundamentally from the arch of the aorta and give rise to the common carotid and subclavian arteries in birds. However, the branching of the brachiocephalic trunk shows differences among the avian species (Nickel et al. 1977; King and McLelland 1984). While a similar vascular organisation can exist among species, variations in vascularisation can also be seen among individuals of the same species. Attempts towards understanding vascular organization with discrete morphological approaches will facilitate the description of species-specific vascularisation and of variations among species. Moreover, the obtained data will assist in anatomy education with regard to wild species.

Several studies have been performed to attempt to describe the branching from the arch of the aorta in different mammalians. For this purpose, rodents (Sinzinger and Hohenecker 1972; Atalar et al. 2003; Aydin 2011), ruminants (Lee and Lee, 1984; Ahn et al. 2008), and carnivores (Rochat and Settles 1993; Ricardo et al. 2001; Kim et al. 2006) have been studied. In addition, pathologic variations of the aortic arch were also investigated in humans and animals (Yarim et al. 1999; Yoo et al. 2003; Yeri et al. 2011), and these variations are reported to be significant occurrences alongside the normal anatomical situation. The number of studies regarding species-specific vascular organisation in avian species is significantly fewer than those performed in mammals. Moreover, the numbers of species-specific studies on the vascular organisation of the aortic arch in recent years are very limited. As far as could be gleaned from a review of the literature, no studies have been performed with the aim of describing the vascular organization of the aortic arch in the Eurasian bittern, a wild water bird whose number is gradually decreasing. In the present study, the aim was to study the vascular branching morphology of the aortic arch in the Eurasian bittern, with the hope that described observations will help in the on-going collection and understanding of vascular organisation in wild water birds.

MATERIAL AND METHODS

The two adult Eurasian bitterns (*Botaurus stellaris*), which died because of traumatic causes (shot by hunters) were used in this study. The animals were 78–80 cm in length, with a 127–130 cm wingspan and a body mass of 1.78–1.85 kg. The latex injection method was used to observe the branching of the aortic arch. Aortic arches and their arteries were evaluated by dissection of the thoracic region. For this purpose, after the apex of the heart was cut, a urinary catheter was inserted into the left ventricle of the heart and fixed by placing a ligature on the ascending aorta. Red coloured latex (10–15 cc) was injected into the arterial system through a catheter, until the blood vessels in the extremities became apparent. The cadavers were kept in a refrigerator (4 °C) for one day to ensure the fixation of the latex. Materials which were dissected under a dissection microscope (ScanOptics-SO5800, Scanoptics Pty., Ltd., Australia) were photographed with a digital camera (Canon SX1-IS, Canon Inc., USA).

RESULTS

Observation revealed that two brachiocephalic trunks were arising separately but adjacent to each other from the arch of the aorta in the Eurasian bittern. The left brachiocephalic trunk was arising first and then the right brachiocephalic trunk was branching off (Figure 1). There was almost no space but a syrinx was seen between the origins of the two brachiocephalic trunks. That is to say, the trunks were arising from the aortic arch ventral to the syrinx and partially ventral to the primary bronchi. The brachiocephalic trunks were giving rise to the common carotid and subclavian arteries 2.5 cm away from their origins on the aorta. While the common carotid arteries were thin and directed cranially, the subclavian arteries were thicker and running laterally (Figure 1).

One of the thin branches arising from the subclavian artery was the sternoclavicular artery, which was in turn dividing into a sternal and a clavicular artery supplying the thoracic inlet and pectoral muscles (Figure 1). Much thinner arteries were also arising from these arteries as they were running into the muscles they supply. After the branching of the sternoclavicular artery, the axillary arteries supplying the forelimbs were originating from the subclavian arteries and were then running deep into the shoulders (Figure 1). The thickest branch of the subclavian artery was the thoracic artery, which was very short and sequentially divided into an internal and an external thoracic artery coursing deep into the pectoral muscles and the lateral wall of the thoracic cavity. Both thoracic arteries were running to the internal wall of the thoracic wall and supplying the pectoral muscles (Figure 1). While the axillary artery was arising from the anterior and dorsal aspects of the subclavian artery, the sternoclavicular and thoracic arteries were originating from the ventral aspect of the same (Figure 1). Furthermore, the external thoracic artery gave rise to a thin dorsal and a ventral branch. While the former was coursing inside the thoracic wall, the latter (intercostal artery) was running caudally toward the last rib (Figure 1).

The brachiocephalic trunks running on both sides give rise to the common carotid arteries which originated from the anterior aspect of the trunks and showed close contact with the thyroid gland at the tracheosyringeal junction (Figure 2). The diameter of the gland was 0.5 cm on average and was supplied by very thin branches (thyroid arteries) originating from the common carotid arteries. Furthermore, as the common carotid arteries were running cranially, they gave rise to tracheosyringeal branches supplying the trachea

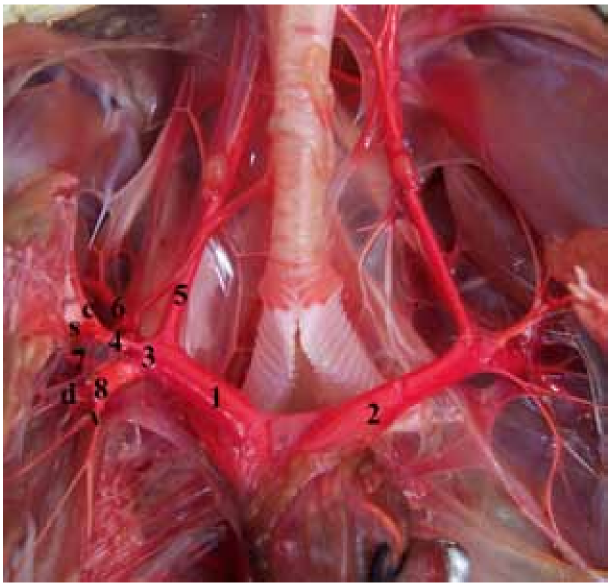

Figure 1. General appearance of aortic arch. Right (1) and left (2) brachiocephalic trunks, subclavian artery (3), sternoclavicular artery (4); sternal (s) and clavicular (c) arteries, common carotid artery (5), axillary artery 6), internal thoracic artery (7), external thoracic artery (8); dorsal (d) and ventral (v) (intercostal artery) branches

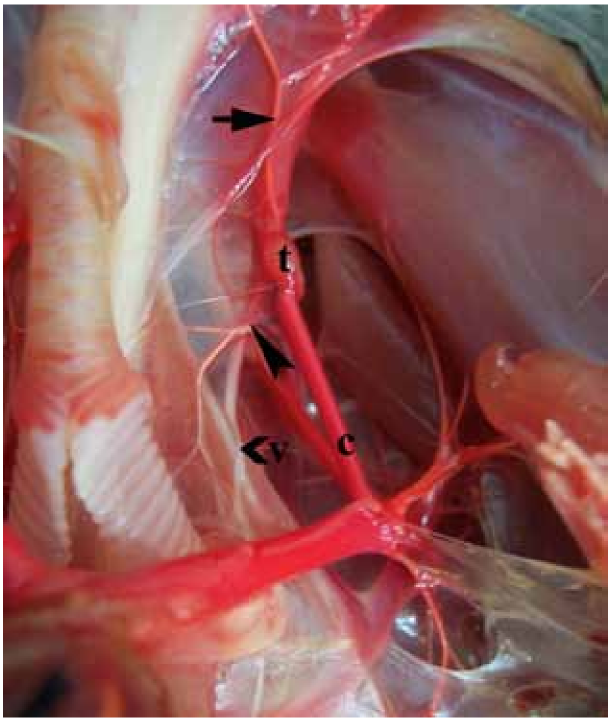

Figure 2. Branches of common carotid artery (c). Thyroid (t), n.vagus (v), ramus tracheosyringealis (arrowhead), a. comes n. vagi (arrow)

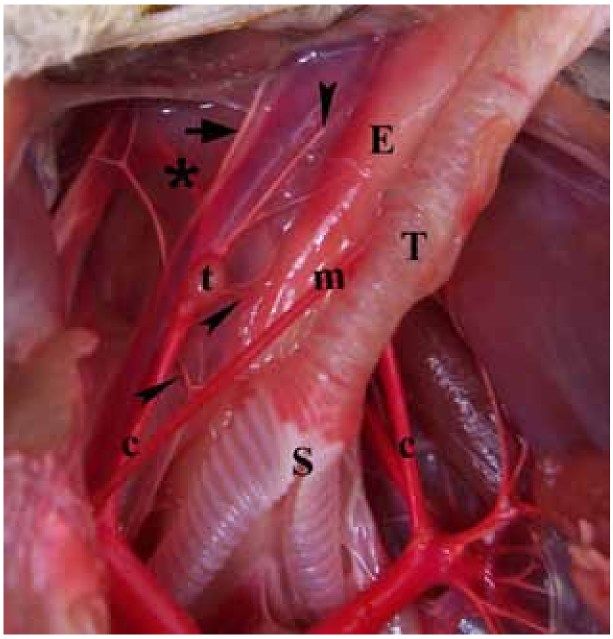

Figure 3. Appearance of arteries in thoracic inlet. Esophagus (E), trachea (T), syrinx (S), sternotracheal muscle (m), common carotid artery (c), thyroid (t), esophageal branches (arrowheads), a. comes n. vagi (arrow), vertebral trunk (*)

and syrinx (Figure 2). The oesophageal branches were also originating from the common carotid arteries where they were touching the thyroid gland (Figure 3). Moreover, the common carotid arteries also gave rise to branches (a.comes n.vagi) contributing blood to cervical muscles, connective tissue and the skin in the area (Figures 2, 3). Finally, the vertebral trunk branched off to the common carotid (Figure 3).

In this study, the entirety of the vessels around the heart was in firm contact with thoracic air sacs and was surrounded with cranially and caudally well-developed thoracic air sacs.

DISCUSSION

Two brachiocephalic trunks (right and left) are shown to arise essentially from the arch of the aorta and giving rise to a common carotid and a subclavian artery in avian species (King and McLelland 1984). The vessels arising from the brachiocephalic trunks supply the head, neck, wings, and pectoral areas of birds (Nickel et al. 1977).

The subclavian artery is reported to extend to the costal processes of the sternum after branching off to the brachiocephalic trunk and serve as origin of the arteries supplying the wings and pectoral area in domestic birds (Nickel et al. 1977). Likewise, we observed that the subclavian artery in the Eurasian bittern, particularly right under the inlet to the thoracic cavity, supplied the forelimbs and pectoral region. We detected the same branching pattern of the brachiocephalic trunks on both sides in the inspected samples. The first vessel branching off from the subclavian artery was the sternoclavicular artery, providing blood to the supracoracoid and pectoral muscles. However, no acromial artery ramifying from the subclavian artery as reported by Nickel et al. (1977) in domestic birds was noted. Furthermore, it was noticed that the axillary artery was a branch ramifying independently from the subclavian artery in contrast to mammals where it is reported to be a continuation of the subclavian artery (Constantinescu 2004). The thickest branch originating from the subclavian artery and supplying the majority of the pectoral area was the thoracic artery. Similar to the report of Nickel et al. (1977), we observed that the external thoracic artery was giving rise to a prominent dorsal and a ventral branch. In addition to the absence of the lateral thoracic artery the internal thoracic artery also showed no dorsal or ventral bifurcation in the Eurasian bittern.

Glenny (1953a) designated the first branch of the subclavian artery as the sterno-clavicular or coracoid artery in the birds of the Apodiformes family. This researcher also reported that the second branch was the pectoral trunk and the axillary artery was a continuation the subclavian artery. In addition, Glenny (1953a) also reported, as an exception, two sternoclavicular arteries branching off the subclavian artery in the members of the Trochilidae family.

The internal thoracic artery is presented to ramify from the posterior aspect of the subclavian artery in Passeriformes (Glenny 1945a), Coliiformes (Glenny 1944), Trogoniformes (Glenny 1948a), and Gruiformes (Glenny 1947) families of birds; in contrast, the internal thoracic artery in the Eurasian bittern was a branch of the external thoracic artery. In addition, the axillary artery is shown to arise from the anterior and dorsal aspects of the subclavian artery in these four families, similar to the Eurasian bittern. The coracoid major artery in the Trogoniformes family (Glenny 1948a) is shown to originate from the subclavian artery. Once more, the coracoid major artery arising from the subclavian artery and the coracoid minor artery originating from the axillary artery are also reported in species of the Coliiformes family (Glenny 1944). In the present case, I believe that the function of the coracoid major artery and the coracoid minor artery are fulfilled by the sternal and clavicular arteries arising from the sternoclavicular artery. In the Colymbiformes family (Glenny 1946), coracoid minor, coracoid major, axillary, and pectoral arteries arise from the subclavian artery, respectively. In contrast to the Coliiformes family (Glenny 1944), the coracoid minor artery does not stem from the axillary artery. Nevertheless, the coracoid minor arteries ramify from the axillary artery in species of *Anthropoides paradise* and *Fulica americana* (Glenny 1947), such as the Coliiformes family (Glenny 1944). Finally, the coracoid major artery in the Gruiformes family (Glenny 1947), is reported to branch off the subclavian artery prior to the origin of the coracoid minor.

The sternoclavicular artery is not present in birds belonging to the Fringillidae (Glenny 1942a), and the coracoid major artery and the intercostal artery (internal mammary artery), were shown to be ramifications of the subclavian artery. Dual internal mammary arteries either arise from the coracoid major artery or directly from the subclavian artery (Glenny 1942a). This vascular organisation is reported to be rather consistent for members of the Fringillidae family (Glenny 1942a). The intercostal artery in *Ara ararauna* (Glenny 1951), was shown to arise from the subclavian artery near to the origin of the coracoid major artery or just lateral to it. Likewise, the intercostal artery in *Grus americana* (Fisher 1955), was shown to be the terminal branch of the subclavian artery. While the order of the branches arising from the subclavian artery in *Grus americana* is axillary, coracoid major, pectoral, and intercostal, this order in *Grus antigone*, which is found in the same class with *Grus americana*, is axillary, pectoral, intercostal, and coracoid major arteries (Fisher 1955). These observations indicate that vascular variations are present among different species of birds in the same class. In the Eurasian bittern this order was the following: sternoclavicular, axillary arteries and thoracic trunk but coracoid arteries were not present and the intercostal artery was arising as a branch of the thoracic trunk. The coracoid minor artery is also not found in *Grus americana* (Fisher 1955); however, the coracoid major artery can arise from the axillary artery just as reported in *Anthropoides paradisea* (Fisher 1955). While the left intercostal artery in the Whooping crane (Fisher 1955) is shown to ramify from the subclavian artery, the right intercostal artery is reported to arise from the thoracic artery, similar to the Eurasian bittern. The intercostal artery in the American bittern (Glenny 1940), was shown to arise from the subclavian artery as its first branch.

In contrast to several water birds (Glenny 1940), the brachiocephalic trunks of the kiwi (Glenny 1942b), give rise to a dorsal and a ventral thyroid artery before giving off the internal carotid and subclavian arteries. The subclavian artery then gives rise to coracoid, intercostal (internal mammary), cutanous, and two pectoral-axillary arteries, in this order. Since the wings of the kiwi (Glenny 1942b) are reduced in size to allow flying, the organisation of blood supply to this region has been reported to be modified. While vessels supply the pectoral muscles in other birds, in kiwis blood is supplied by thin branches; therefore, the pectoral arteries are designated as pectoral-axillary arteries in the kiwi.

It was noted that the common carotid artery gave rise to the thyroid artery, tracheosyringeal artery, and esophageal branches in the Eurasian bittern. Similarly, in several bird families such as Gaviiformes (Glenny 1945b), Charadriiformes (Glenny 1948b), Caprimulgiformes (Glenny 1953b), and Coliiformes (Glenny 1944), the common carotid artery gives rise to a syringe-tracheal artery and mesooesophageal artery at the furcula level. The presence of an accessory oesophageal artery originating from the carotid artery in *Gavia stellata* was also reported by Glenny (1945b) but such a branch was not noted in the Eurasian bittern. In contrast to several birds, the thyroid arteries of the kiwi (Glenny 1942b), were shown to originate directly from the brachiocephalic trunks. Three thyroid arteries, cranial, middle, and caudal, have been reported in the budgerigar and their number is also different among individuals of the same family (Radek and Piasecki 2004). The thyroid artery was originating from the carotid artery near to the thyroid gland in the Eurasian bittern.

In summary, in this study the vascular organisation and branching of the brachiocephalic trunks in the Eurasian bittern were determined. It is hoped that the presented results will facilitate understanding of the phylogenetic relationships and morphological resemblances among different species. In addition, I believe that these data will contribute to a better understanding of previous reports on vascular organisation and will aid elucidation of the differences among further bird species in the future. Finally, such studies will elucidate the vascular organisation of regional blood supplies and provide specific anatomical data regarding the Eurasian bittern.

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