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Ramification of the celiac artery in the greater flamingo (*Phoenicopterus roseus*)

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ABSTRACT: The purpose of this study was a description of the species-specific characteristics of the celiac artery in greater flamingos (*Phoenicopterus roseus)*. In the greater flamingos examined in this study, it was observed that the celiac artery (*a. celiaca*) originated from the right ventrolateral surface of the descending aorta (*aorta descendens*) at the level of the fourth thoracic intervertebral junction. The celiac artery was observed to give off branches to the oesophagus, proventriculus, gizzard, spleen, liver, gall bladder, duodenum, pancreas, jejunum, ileum and caecum. After giving off the dorsal proventricular artery (*a. proventricularis dorsalis*) and oesophageal artery (*ramus esophagealis*), the celiac artery bifurcated into two main branches. It was determined that the right branch of the celiac artery (*ramus dexter*) gave off either two or four splenic arteries (*aa. splenicae*), as well as the right hepatic artery (*a. hepatica dextra*), duodenojejunal artery (*a. duodenojejunalis*), right dorsal gastric artery (*a. gastrica dextra dorsalis*), right ventral gastric artery (*a. gastrica dextra ventralis*) and pancreaticoduodenal artery (*a. pancreaticoduodenalis*). The ventral proventricular artery (*a. proventricularis ventralis*), left hepatic artery (*a. hepatica sinistra*), the arterial branches to the saccus cranialis (*rami saccicraniales*) and the left gastric artery (*a. gastrica sinistra*) arose from the left branch of the celiac artery (*ramus sinister*).

Keywords: anatomy; circulation; branching celiac artery; flamingo

The celiac artery is the first major ventral branch of the descending aorta (Nickel et al. 1977; Kuru 2010). Most literature reports indicate that the avian celiac artery bifurcates into two main branches, which are referred to as the *ramus dexter* and *ramus sinister* (Baumel et al. 1993; Aslan and Takci 1998; Kurtul and Haziroglu 2004; Geeverghese et al. 2012). However, it has also been reported that, in the pigeon and the eagle owl, the celiac artery does not divide into two branches and all of the branches given off by the celiac artery arise from a common root (Chiasson 1982; Aycan and Duzler 2000). In avian species, the branches given off by the celiac artery generally supply the proventriculus, gizzard, liver, pancreas, spleen and small intestine (Evans 1970; Nickel et al. 1977; Silva et al. 2005; Vasconcelos et al. 2012; Neto et al. 2013).

MATERIAL AND METHODS

Two female and three male greater flamingos (*Phoenicopterusroseus*) were included in this study. Of these birds, two had died during the treatment of traumatic wounds, after being admitted to the surgery clinic of Erciyes University, Faculty of Veterinary Medicine. The other three birds had been brought dead to the Faculty of Veterinary Medicine by a bird watcher. The mean body weight of the birds was 2.83 kg (from 2.7 to 3.15 kg). Their wingspan ranged between 130 and 186 cm, and their height ranged from 120 to 159 cm. Through the left ventricle, latex coloured with red ink was injected into the aorta. After being kept in water for a period of 48 h to ensure complete polymerisation of latex the birds were placed into 10% formaldehyde. Subsequently, the flamingos were dissected under an Olympus ZS STB1 microscope.

RESULTS

In all five of the greater flamingos examined, it was observed that the celiac artery originated from the right ventrolateral surface of the descending aorta, at the level of the third/fourth thoracic in-

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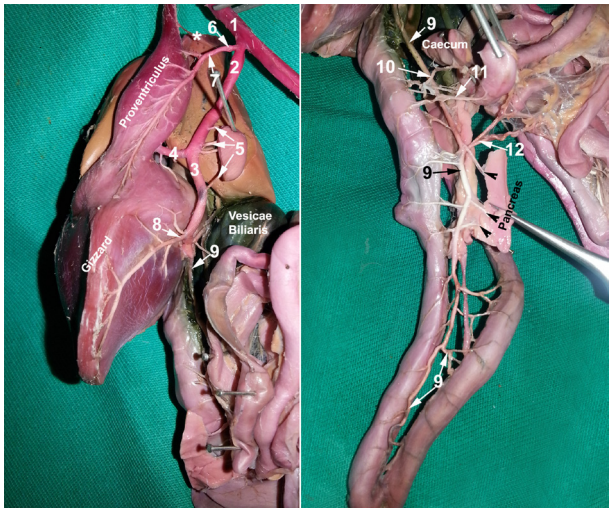

Figure 1. The celiac artery in the greater flamingo

tervertebral junction and in the proximity of the very beginning of the proventriculus. It was ascertained that the greater flamingos had six pairs of ribs (costae) and that the origin of the celiac artery was at the level of the fourth pair of costae. The mean diameter of the celiac artery at its origin was 3.4 mm.

The first branch given off by the celiac artery was the dorsal proventricular artery that extended up to the level of the proventriculus on the left, and then curved ventrocaudally, traversing to the level of the musculus lateralis dorsalis of the gizzard. Along its course, the artery gave off branches ranging from four to nine in number, which divided into finer and finer branches that formed a fan-like distribution towards the proventriculus (Figure 1/7). The first branch given off by the dorsal proventricular artery, that extended cranially, was the *ramus oesophagealis* (Figure 1/*). This branch, which followed an anterior path, was distributed to the oesophagus. In all of the greater flamingos examined in this study, the celiac artery was observed to have bifurcated into the *ramus dexter* and *ramus sinister*, at a mean distance of 29.6 mm from its origin.

Ramus dexter (Figure 1/3, 2/3, 3/2): Of the two main branches of the celiac artery, the *ramus dexter* was longer and larger than the *ramus sinister*. It curved caudoventrally and extended between the gizzard and gall bladder. The mean diameter of the *ramus dexter* was 2.6 mm near its origin. It was observed that the *ramus dexter* sequentially gave rise to the splenic arteries, right hepatic artery, an artery to the gall bladder, duodenojejunal artery, right dorsal gastric artery, right ventral gastric artery, pancreaticoduodenal artery, ileocecal artery and jejunal artery in each of the flamingos.

In three of the flamingos examined, four splenic arteries were present and of these the first three arose from the celiac artery, and the last originated from the *ramus dexter* (Figure 2/A). The other two flamingos had two splenic arteries and both of these originated from the *ramus dexter* (Figure 2/B). In three of the five flamingos the right hepatic artery was observed to arise from the *ramus dexter* (Figure 3/8) while in the other two, the right hepatic artery originated from the *ramus sinister.* In all five of the flamingos examined in this study, the artery to the gall bladder (*a. vesicae biliaris*) originated from the right hepatic artery.

It was determined that the duodenojejunal artery had a mean diameter of 0.9 mm where it arose from the right surface of the *ramus dexter.* In one of the flamingos a single blood vessel given off by the duodenojejunal artery extended to the gall bladder.

Three to four fine branches, arising from the *ramus dexter* at the level of the origin of the duodenojejunal artery were observed to extend to the

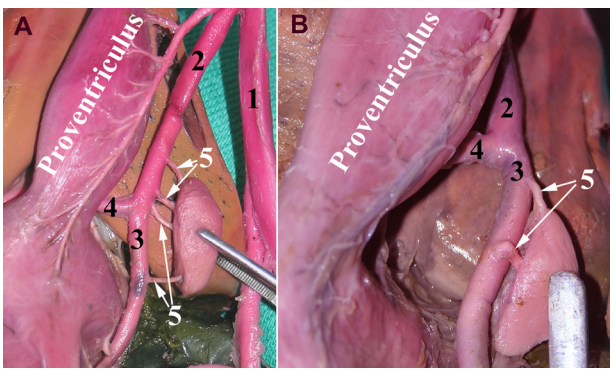

Figure 2. Splenic arteries in the greater flamingo

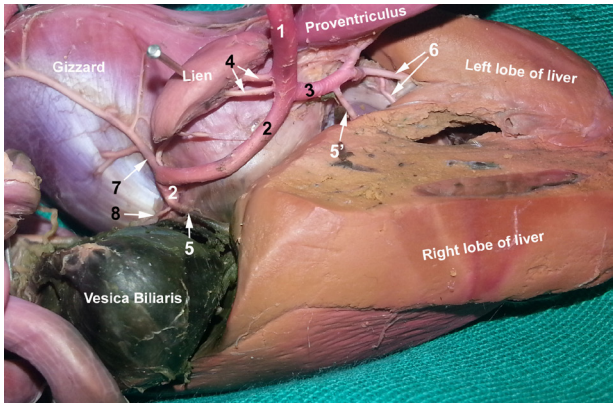

Figure 3. Hepatic arteries in the greater flamingo

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gizzard and the beginning of the duodenum. The right dorsal gastric artery was observed to stem from the *ramus dexter* and extend to the dorsal part of the gizzard. After giving off the right dorsal gastric artery, the *ramus dexter* extended ventrocaudally for a mean distance of 2.8 mm and bifurcated into the right ventral gastric artery and the pancreaticoduodenal artery. The right ventral gastric artery extended along the ventrocaudal surface of the gizzard, giving off several branches.

It was observed that the pancreaticoduodenal artery followed a path between and parallel to the duodenum and pancreas. Three to four branches given off by the pancreaticoduodenal artery were observed to be distributed to the pancreatic tissue (Figure 1). The pancreaticoduodenal artery extended up to the level of the flexura duodeni, giving off bilateral branches to the pars ascendens and pars descendens of the duodenum at different distances (Figure 1). At a mean distance of 30 mm from its origin, it gave off the ileocecal artery, which extended to the caecum and ileum (Figure 1). Distal to the origin of the ileocecal artery the jejunal artery arose from the pancreaticoduodenal artery and was the sole arterial supply to the jejunum.

Ramus sinister (Figure 1/4, 2/4, 3/3): In all of the flamingos examined, the *ramus sinister* was thinner than the *ramus dexter* having a mean diameter of 2.3 mm at its origin. The ramus sinister sequentially gave rise to the ventral proventricular artery, left hepatic arteries, arterial branches of the saccus cranialis of gizzard and left gastric artery. In one of the flamingos a single hepatic arterial branch extended to the right lobe of the liver from the ramus sinister at a mean distance of 4.2 mm from the coeliac bifurcation (Figure 3/5'). In all of the flamingos the *ramus sinister* gave rise to the ventral proventricular artery at a mean distance of 8 mm to its origin. This artery was distributed to the proventriculus and extended up to the level of the oesophagus as fine arborising branches. In all flamingos examined the left hepatic artery stemmed from the *ramus sinister*, distal to the origin of the ventral proventricular artery. In two of the five flamingos examined, it was observed that a single slender artery stemming from the *ramus sinister* extended to the cranial sac of the gizzard. Later, the *ramus sinister* bifurcated into two main branches. Of these branches, the fine one with an average diameter of 1.5 mm curved to the right towards the cranial. Along its course, it gave off two left hepatic arteries to the left lobe of the liver and two saccus cranialis arterial branches to the cranial sac of the gizzard. It was determined that in examined flamingos, the left lobe of the liver was vascularised by three left hepatic arteries. The arterial branches of the saccus cranialis were formed by two blood vessels in three of the flamingos, and by three blood vessels in the other two flamingos. The major branch, referred to as the left gastric artery, which was the continuation of the *ramus sinister*, had a mean diameter of 1.9 mm. This artery was distributed to the left surface of the gizzard in the form of several branches, two of which were major branches.

DISCUSSION

In the present study, it was observed that the celiac artery originated at the level of the third/fourth thoracic intervertebral junction and the fourth pair of costae in all of the flamingos examined. These findings resemble only those reported in the cattle egret (Khalifa 2014). Similarly to the chicken (Silva et al. 2005; Kuru 2010), quail (Duzler et al. 2011), goose (Ragab et al. 2013) and cattle egret (Khalifa 2014) the celiac artery originated from the right surface of the descending aorta in all of the flamingos.

Literature reports indicate that in some bird species the first branch arising from the celiac artery is the oesophageal artery (Malinovsky et al. 1973, domestic duck; Silva et al. 1997, *Gallus gallus domesticus*; Kuru 2010, domestic fowl; Geeverghese et al. 2012, domestic pigeons; Ragab et al. 2013, domestic goose; Khalifa 2014, cattle egret). In several other bird species (budgerigar and domestic chicken, Evans 1970; Goncalves et al. 2011, blue-fronted amazon; Atalgin et al. 2012, heron; Neto et al. 2013, green-billed toucan), it was shown that the first branch of the celiac artery was the dorsal proventricular artery. However it has been observed that in some species the oesophageal artery and dorsal proventricular artery originated from the celiac artery as a common root (Duzler et al. 2011, Japanese quail; Vasconcelos et al. 2012, ostrich; Neto et al. 2013, green-billed toucan). Regarding the arteries supplying the oesophagus, Malinovsky and Visninska reported that in the goose the oesophageal artery stemmed from the aorta, while the rami oesophageales stemmed from the celiac artery

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and the dorsal proventricular artery (Malinovsky and Visninska 1975). In the flamingos examined in the present study, the ramus oesophagealis was observed to have stemmed from the dorsal proventricular artery. No independent artery extended to the oesophagus from either the celiac artery or the aorta; i.e. no oesophageal artery was found in these birds.

In several studies conducted on a variety of avian species (Malinovsky and Novotna 1977, domestic fowl; Pinto et al. 1998, domestic duck; Kurtul and Haziroglu 2004, rooster, drake, and pigeon; Silva et al. 2005, female fowls; Kuru 2010, domestic fowl; Haligur and Duzler 2010, red falcon; Geeverghese et al. 2012, domestic pigeons; Vasconcelos et al. 2012, ostrich), it has been reported that the celiac artery bifurcates into the *ramus dexter* and the *ramus sinister*. The bifurcation of the coeliac artery of the flamingos examined in the present study supports these earlier findings. Interestingly, some other studies (Chiasson 1982, pigeon; Aycan and Duzler 2000, eagle owl) do not report such a bifurcation. Aslan and Takci (1998) reported that, in geese, the *ramus dexter* and *ramus sinister* were of an equal diameter. In the flamingo, similar to the grey heron (Atalgin et al. 2012) and the domestic goose (Ragab et al. 2013), the *ramus dexter* had a larger diameter than the *ramus sinister*.

The origin and number of the splenic arteries vary among avian species. It has been reported that the splenic arteries originate from the celiac artery, dorsal proventricular artery, *ramus sinister* and *ramus dexter* (Malinovsky and Novotna 1977; Silva et al. 1997; Pinto et al. 1998; Aslan and Takci 1998; Haligur and Duzler 2010; Kuru 2010; Duzler et al.2011; Goncalves et al. 2011; Atalgin et al. 2012; Geeverghese et al. 2012; Vasconcelos et al. 2012; Neto et al. 2013; Ragab et al. 2013; Khalifa 2014). In three of the flamingos in the present study, three splenic arteries arose directly from the celiac artery, and the fourth originated from the *ramus dexter*. In the other two flamingos examined, the splenic arteries were observed to have their origin from the *ramus dexter*, which is similar to what has been reported for domestic ducks, domestic geese, Japanese quail and green-billed toucans.

Literature reports suggest that the hepatic arteries stem, either independently or in the form of a common root, from the *ramus sinister, ramus dexter* and *ventral gastric artery*. In this study of five flamingos, we found that in two birds, the right hepatic artery arose from the *ramus dexter*. In another two birds the right hepatic artery stemmed from the *ramus sinister*. In the fifth flamingo it was observed that two separate right hepatic arteries originated as one vessel from each ramus. In all of the flamingos examined, the left hepatic artery originated from the *ramus sinister*. It was observed that in the flamingo the hepatic arteries have a species-specific hepatic artery distribution that differs from that of other avian species reported previously.

It has been reported that in the red falcon the *a. vesicaebiliaris* arises from the *ramus sinister* (Haligur and Duzler 2010). The majority of literature reports refer to the artery supplying the gall bladder as a branch of the right hepatic artery (Malinovsky and Novotna 1977, domestic fowl; Baumel et al. 1993, various avian species; Aycan and Duzler 2000, eagle owl; Kuru 2010, domestic fowl; Duzler et al. 2011, Japanese quail; Vasconcelos et al. 2012, ostrich). The findings of the present study support these earlier reports. However, in one of the flamingos, an additional artery to the gall bladder that arose from the duodenojejunal artery was found.

In conclusion, in the present study, features of the celiac artery, which were specific to the greater flamingo, were determined and compared to the literature available for other bird species.

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