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Morphometry and topography of the coronary ostia in the dog

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Abstract

Introduction: The purpose of this study was to perform a morphometric examination of the coronary ostia, including their location in the area of the aortic sinuses, and to describe variations in ostia structure in the domestic dog. **Material and Methods:** The study was conducted on the hearts of 91 pedigree dogs of both sexes, aged 1 to 18 years (median 9 years), with a body weight from 1.2 to 65 kg (median 20.7 kg). Morphometric examinations of the coronary ostia were performed in the studied individuals, and the location of the structures in relation to the intercommissural lines was determined. **Results:** Three types of location of the coronary ostia were distinguished, *i.e.* below the intercommissural line (type I), on the intercommissural line (type II), and above the intercommissural line (type III). In the studied dogs, the most common location of the ostia was type I – found in the left coronary artery of 74/91 dogs (81%) and in the right coronary artery of 42/91 dogs (46%). Morphological variations were shown in 36/91 dogs (40%) in the structure of the coronary ostia, including the presence of accessory ostia. The most common variation was the presence of an accessory ostium near the ostium of the right coronary artery, which was found in 28/91 dogs (31%). **Conclusion:** The results may be useful in developing standards for procedures to replace the whole or part of the aortic valve and repair the coronary artery.

Keywords: coronary ostia, coronary arteries, dog.

Introduction

In the domestic dog, the aortic valve is located in the ascending aorta and comprises three semilunar leaflets: right, left, and non-coronary. The aortic sinus of the left and right semilunar leaflets contains coronary ostia. According to the Nomina Anatomica Veterinaria (45), two main vessels supply blood to the heart muscle – the left and right coronary arteries (LCA and RCA). However, various deviations from this regularity have been described in both medical and veterinary literature. These include *inter alia* the absence of an RCA (33) and presence of an accessory coronary artery (30). In human medicine, particular components of the aortic valve, including the coronary vessels, undergo morphometric evaluation as part of the diagnostic process; it is commonly performed as preparation for endovascular procedures during heart catheterisation, such as coronary angiography and angioplasty (25, 27, 42). Morphological variations related to the location of coronary ostia may lead to myocardial ischaemia, infarction, and sudden death. It should be emphasised that the presence of accessory coronary vessels or a single coronary artery (SCA) are recognised as rare anomalies in about 1% of patients (15, 28, 40). Variations associated with the location of coronary ostia were found in 0.3% of cadavers in a necropsy series and in 1.6% of patients undergoing coronary angiography (27). Coronary artery anomalies are rarely described in veterinary literature (29, 32, 39). According to Scansen (39) the most well-known anomaly in dogs is an anomalous coronary artery origin with a prepulmonary course. French bulldogs, English bulldogs and boxers are predisposed to the development of coronary anomalies. In English bulldogs examples of anomalous coronary artery origins were presented by Scansen (39): single left coronary ostium and retroaortic RCA, single right coronary ostium and transseptal LCA, and single right coronary ostium and absent LCA.

In veterinary medicine, studies on aortic valve structure and the topography and morphometry of ostia have been carried out in various mammalian species, such as equines (36), sheep and swine (35), donkeys (34), domestic cats (3, 4), cattle (19, 20), European bison (6), and chickens (9). The most commonly observed differences include the location of the ostia in the area of specific aortic sinuses, the symmetry of the ostia, the presence of accessory ostia, and variability in the structure of the common trunk of coronary arteries.

The purpose of this study was to perform morphometry of the coronary artery ostia, including their location in the area of the aortic sinuses, and to describe variations in the structure of the ostia in the domestic dog. The observations herein based on the domestic dog are the continuation of a series of studies conducted on other animal species (3, 4, 6, 7).

Material and Methods

The study included 91 pedigree dogs, 50 females and 41 males, aged from 1 to 18 years with a median (interquartile range, IQR) of 9 (5 to 12) years. They belonged to 33 breeds, of which six were represented by more than five individuals: French bulldog (n = 9), Yorkshire terrier and boxer (n = 8 each), dachshund (n = 7), American Staffordshire terrier, and German shepherd (n = 6 each). Their body weights ranged from 1.2 to 65 kg, with a median (IQR) of 20.7 (7.3 to 33.2) kg.

The observations were made on dogs that had been euthanised by veterinarians at the Small Animal Clinic of the Institute of Veterinary Medicine, Warsaw University of Life Sciences – SGGW. The procedure was performed for various medical reasons excluding cardiac disorders, and informed written consent was given by the owners. Under applicable Polish law, the use of *post-mortem* animal tissues does not require the approval of the Ethics Committee (17). None of the individuals were euthanised for the sake of the study. The anatomical nomenclature used by the authors conformed with the standards of the Nomina Anatomica Veterinaria (45).

In order to visualise the coronary ostia, the ascending aorta was cut off above the commissure of the aortic valve leaflets and an incision was made between the semilunar leaflets. Morphological and morphometric observations were performed using a Halolux150 operating microscope (Ecleris, Buenos Aires, Argentina), Global Surgical Corporation microscope support (MW 725F-I), and software for image metric analysis (AxioVision Rel. 4.7, Carl Zeiss MicroImaging GmbH, Jena, Germany).

Topography of the coronary ostia. The location of the ostia of the LCA and RCA, in the area of the respective aortic sinuses, was established in relation to the intercommissural lines; these were identified on the operating microscope image by connecting the adjacent aortic valve commissures at the site of their attachment on the wall of the ascending aorta (Fig. 1). Both coronary arteries demonstrated three types of ostia position in relation to the intercommissural lines, *i.e.* type I – below the intercommissural line, type II – on the intercommissural line, and type III – above the intercommissural line (3, 14, 35, 36).

The presence of variants related to the structure of the main ostia of the coronary arteries and the presence of accessory ostia were described.

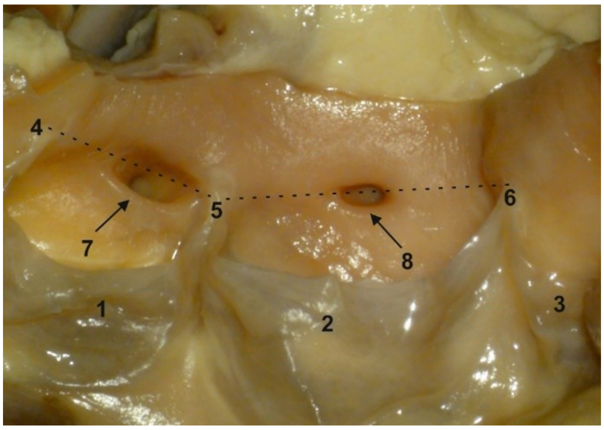

Fig. 1. Overview of aortic valve of the dog. Dotted lines – sinotubular junction; 1 – left semilunar leaflet; 2 – right semilunar leaflet; 3 – septal semilunar leaflet; 4 – left aortic valve commissure; 5 – intermediary aortic valve commissure; 6 – right aortic valve commissure; 7 – left coronary ostium; 8 – right coronary ostium

Morphometry of the coronary ostia. Two dimensions of ostia were directly measured in mm: the longer dimension referred to width and the shorter dimension referred to height. Ostium diameter was calculated as the arithmetic mean of width and height. The dimensions of ostia were not measured when the trunk could not be identified (when the ostium was divided, as observed in 12 dogs).

Statistical analysis. Numerical variables were presented as the median, interquartile range (IQR), and range because of the lack of normal distribution (assessed by visual inspection of histograms and using the Shapiro–Wilk test). The dimensions of coronary ostia were compared between groups using the Mann–Whitney U test and between sides using the Wilcoxon signed rank test. Correlation between numerical variables was determined using Spearman's rank correlation coefficient (R_s). Categorical variables were expressed as the count and percentage in a group and compared between groups using the maximum likelihood G test and between sides using McNemar's test. The 95% confidence intervals (CI 95%) for proportions were calculated using the Wilson score method. All tests were two-tailed. A significance level (α) was set at 0.05 and the Bonferroni correction was applied in the case of multiple comparisons. Statistical analysis was performed in TIBCO Statistica 13.3 (TIBCO Software Inc., Palo Alto, CA, USA).

Results

In all dogs included in the study (n = 91), the aortic valve consisted of three semilunar leaflets: left, right, and non-coronary. The left and right coronary ostia were located in corresponding aortic valve sinuses. The typical location of the left ostium was type I (81.3%), while in the case of the right ostium type I and type II occurred similarly often (46.1% and 39.6%, respectively). Type III was the least frequent on both sides (Fig. 2).

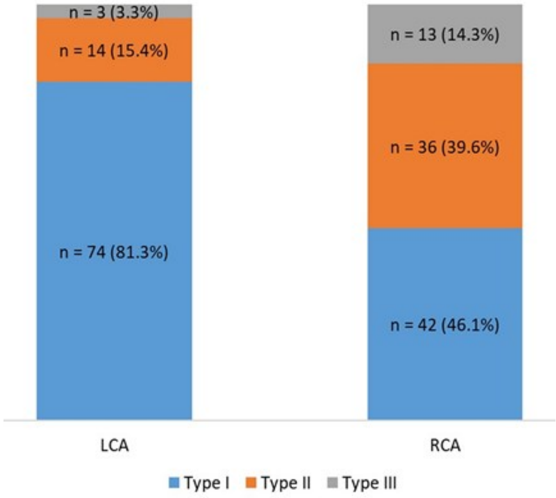

Fig. 2. Distribution of types of ostium location in left (LCA) and right (RCA) coronary artery of 91 dogs

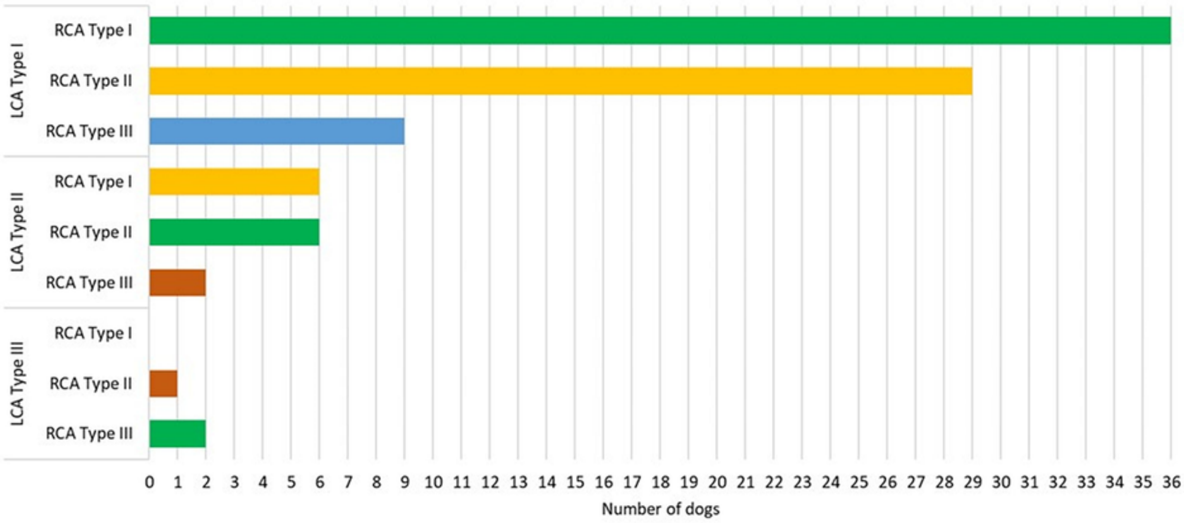

Fig. 3. Combinations of types of ostium location in left (LCA) and right (RCA) coronary artery of 91 dogs. Green bar – same types of location in both coronary arteries. Shared colour bars – location type combinations which only differ in laterality

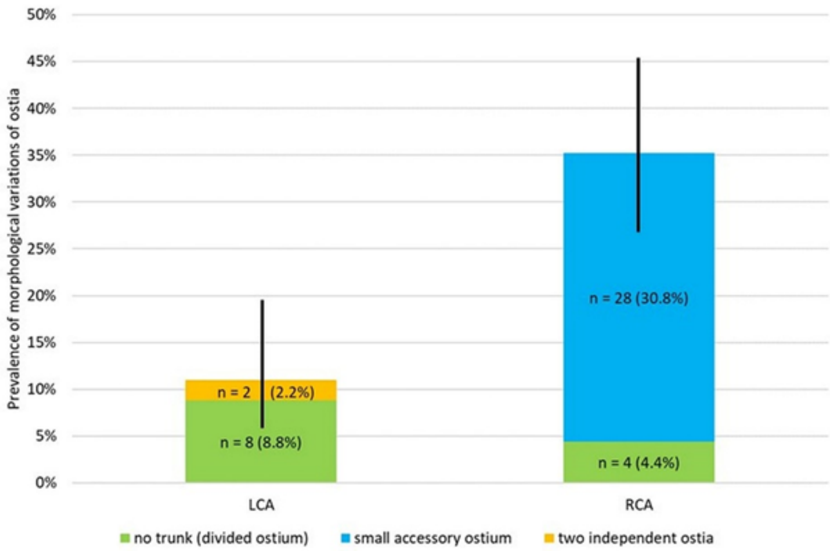

Fig. 4. Prevalence of three types of morphological variations of ostia in left (LCA) and right (RCA) coronary artery of 91 dogs. Black lines – 95% confidence intervals (CI 95%)

The location neither differed between males and females nor was linked to the body weight of the dog either in the LCA (P = 0.125 and P = 0.115, respectively) or the RCA (P = 0.751 and P = 0.268, respectively). The left and right ostium had the same location in 44 dogs (48.4%) (including 1 dog having two left ostia, of which only one had the same location as the right one, the other one having a different location). In these 44 dogs, type I was identified in 36 dogs (81.8%) while type II and type III were recognised in only 6 (13.6%) and 2 (4.6%) dogs, respectively. In 47 dogs the type of ostium location differed between the sides. The most common combination of inconsistent locations of coronary ostia was type I and type II, which occurred in 35/47 dogs (74.5%). The combination of type III and type I was observed in 9/47 dogs (19.1%), and that of type III and type II in 3/47 dogs (6.4%) (Fig. 3).

In 36/91 dogs (39.6%, CI 95%: 30.1%–49.8%) variations associated with the morphology of at least one ostium were observed. The prevalence of anatomical deviations did not differ significantly between males (17/41; 41.5%) and females (19/50; 38.0%) (P = 0.737).

Morphological variations of ostia were observed only in the RCA in 26/36 dogs (72.2%), only in the LCA in 4/36 dogs (11.1%), and in both coronary arteries in 6/36 dogs (16.7%). Morphological variations of ostia were significantly more common in the RCA (35.2%; CI 95%: 26.1%–45.4%; 32/91 dogs) than in the LCA (11.0%, CI 95%: 6.1%–19.1%; 10/91 dogs; P < 0.001). Three different types of morphological variation were observed: no trunk (divided ostium), which was the only one observed in both coronary arteries; small accessory ostium, which was the most common but present only in the RCA; and two independent ostia, which was the least common (occurring only in 2 dogs) and present only in the LCA (Figs 4, 5 and 6). The prevalence of anatomical deviations was not linked to any specific location of ostium (Fig. 7).

Dogs with inconsistent types of ostium location (*i.e.* different in LCA to in RCA) were as likely to have abnormalities as dogs with consistent types of ostium location (P = 0.799) – an abnormal ostium location was observed in 18/44 dogs (40.9%) with consistent locations and in 18/47 dogs (38.3%) with inconsistent location.

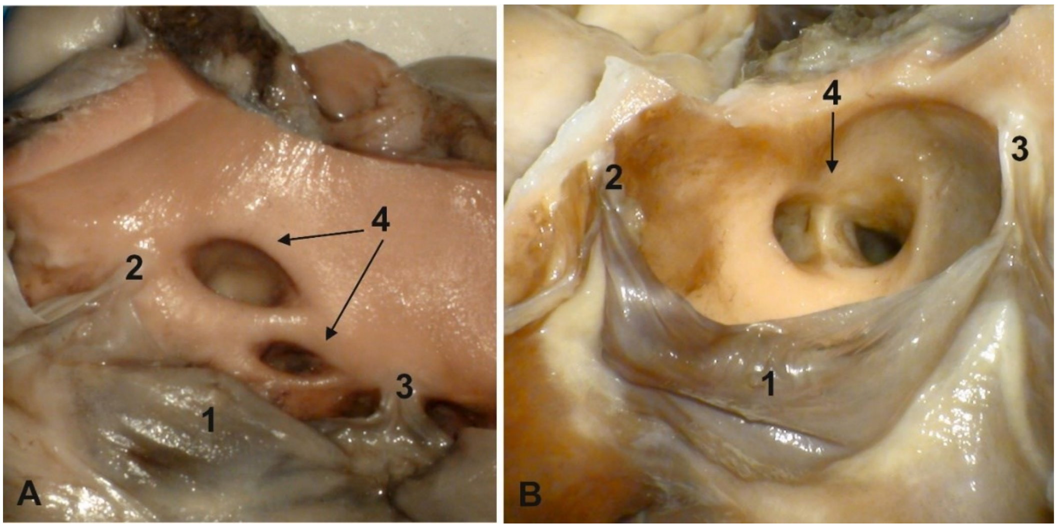

Fig. 5. Overview of left aortic sinus of the dog. A – two independent ostia, B – no trunk. 1 – left semilunar leaflet; 2 – left aortic valve commissure; 3 – intermediary aortic valve commissure; 4 – left coronary ostium

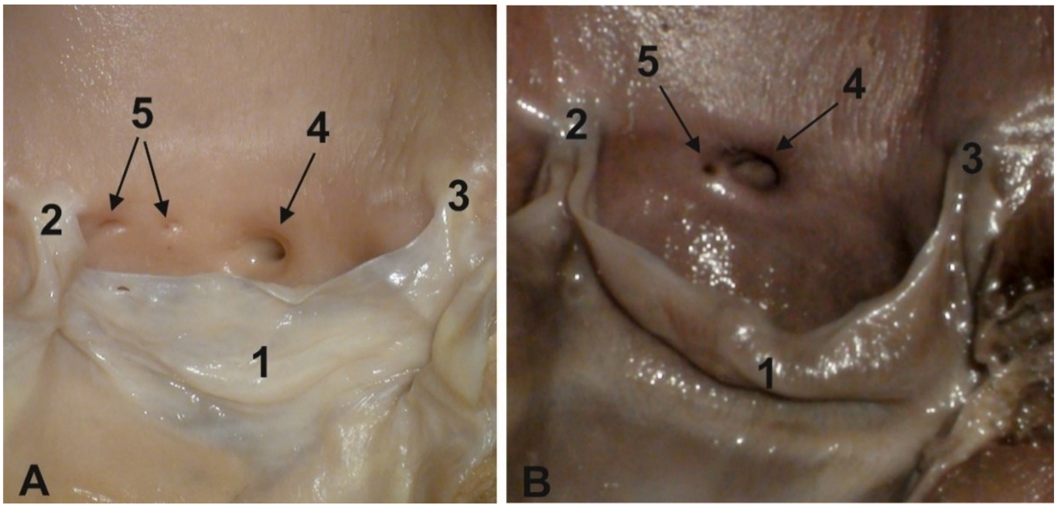

Fig. 6. Overview of right aortic sinus of the dog. A, B – the accessory coronary ostia. 1 – right semilunar leaflet; 2 – intermediary aortic valve commissure; 3 – right aortic valve commissure; 4 – right coronary ostium; 5 – accessory coronary ostium

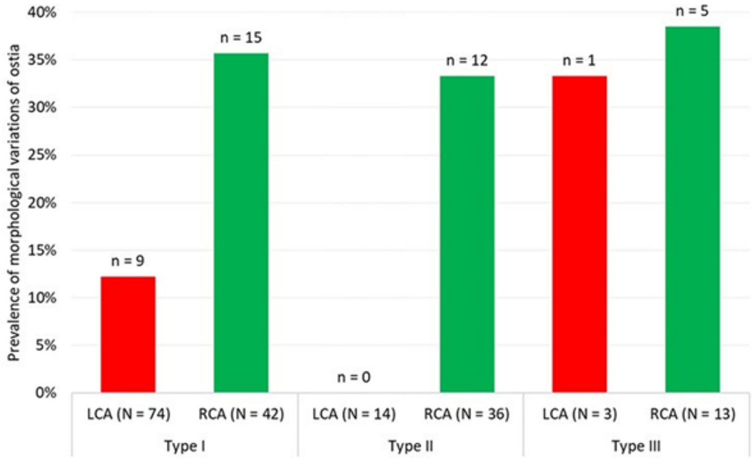

Fig. 7. Prevalence of morphological variations of ostia depending on ostium location type in left (LCA) and right (RCA) coronary artery of 91 dogs

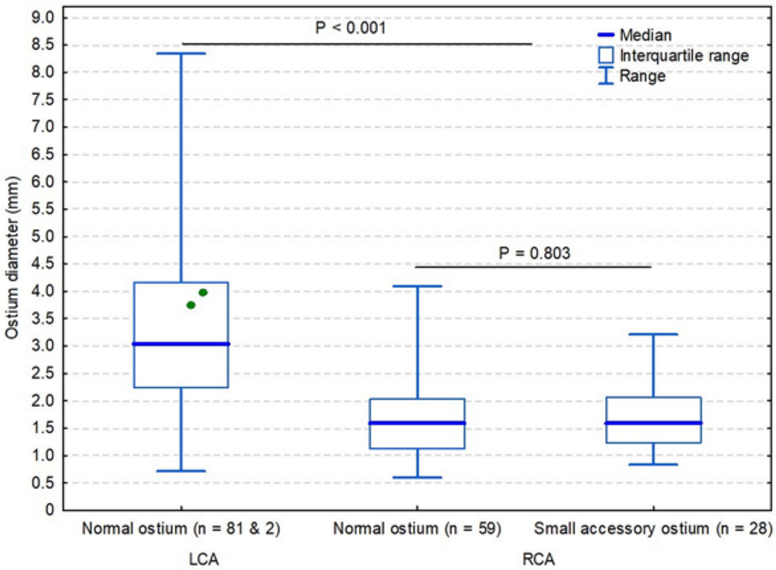

Fig. 8. Ostium diameters (arithmetic mean of width and height) of left (LCA) and right (RCA) coronary artery. Green dots – mean diameters of two independent ostia observed in LCA of two dogs. Divided ostia are not presented in this figure

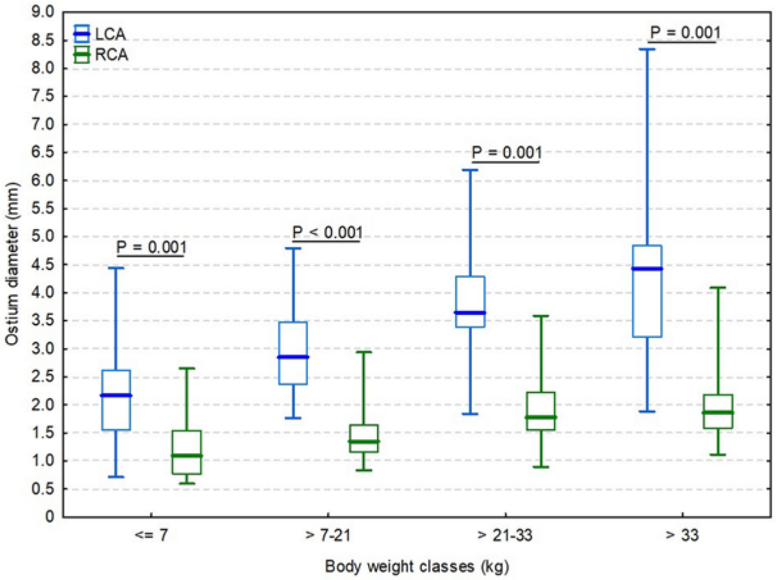

Fig. 9. Ostium diameter (arithmetic mean of width and height) of right (RCA) and left (LCA) coronary artery, presented as median (bold line), interquartile range (box), and range (whiskers), in four body weight classes based on three quartiles of the body weight distribution. P-values derived from the Wilcoxon signed rank test apply to the comparison of ostium diameter between LCA and RCA within each body weight class

Table 1. Detailed dimensions of three types of ostia (excluding divided ostia) of left (LCA) and right (RCA) coronary artery presented for all dogs with a particular type of ostium (overall) and separately for four body weight classes based on three quartiles of the body weight distribution. Dimensions of ostia are summarised as median, interquartile range, and range

Type of ostium	Body weight class	LCA				RCA			
		n	Width (mm)	Height (mm)	Mean diameter (mm)	n	Width (mm)	Height (mm)	Mean diameter (mm)
Normal	Overall	81	3.8, 2.8–5.2 (0.9–10.9)	2.3, 1.5–3.0 (0.5–5.8)	3.0, 2.3–4.2 (0.7–8.4)	59	2.2, 1.5–2.9 (0.8–6.7)	1.0, 0.7–1.2 (0.4–3.0)	1.6, 1.1–2.0 (0.6–4.1)
	≤ 7 kg	22	2.5, 1.9–3.4 (0.9–5.3)	1.5, 1.0–2.0 (0.5–4.1)	2.2, 1.6–2.6 (0.7–4.4)	20	1.3, 1.1–1.9 (0.8–3.5)	0.7, 0.5–1.0 (0.4–1.8)	1.1, 0.8–1.4 (0.6–2.7)
	> 7–21 kg	21	3.3, 2.8–4.2 (2.0–5.8)	2.2, 1.7–2.5 (1.1–3.8)	2.8, 2.4–3.3 (1.8–4.8)	15	1.8, 1.6–2.8 (1.4–4.1)	0.9, 0.7–1.1 (0.6–2.6)	1.4, 1.2–2.0 (1.0–2.7)
	> 21–33 kg	18	4.6, 3.8–5.5 (2.5–9.2)	2.8, 2.2–3.0 (1.1–5.0)	3.6, 3.4–4.3 (1.8–6.2)	12	2.5, 2.2–3.4 (1.6–6.1)	1.2, 1.0–1.5 (0.7–2.2)	1.8, 1.6–2.6 (1.2– 3.6)
	> 33 kg	20	5.2, 4.1–6.1 (2.4–10.9)	3.1, 2.1–4.1 (1.3–5.8)	4.4, 3.2–4.8 (1.9–8.3)	12	2.5, 2.4–4.4 (2.3–6.7)	1.2, 0.9–1.5 (0.6–3.0)	1.9, 1.8–3.1 (1.6–4.1)
Small accessory ostium	Overall	0	-	-	-	28	1.8, 1.5–2.7 (1.0–4.9)	1.2, 1.0–1.4 (0.6–2.7)	1.6, 1.2–2.1 (0.8–3.2)
	≤ 7 kg	-	-	-	-	2	1.8 & 2.8	1.3 & 1.3	1.5 & 2.1
	> 7–21 kg	-	-	-	-	9	1.5, 1.2–1.8 (1.0–4.9)	1.0, 1.0–1.1 (0.7–1.6)	1.3, 1.1–1.6 (0.8–2.9)
	> 21–33 kg	-	-	-	-	8	2.3, 1.6–2.8 (1.2–2.9)	1.4, 0.9–1.5 (0.6–2.1)	1.9, 1.3–2.2 (0.9–2.4)
	> 33 kg	-	-	-	-	9	1.9, 1.7–2.7 (1.2–3.7)	1.2, 1.0–1.7 (0.7–2.7)	1.6, 1.2–2.0 (1.1–3.2)
Two independent ostia		2	4.5 & 5.1	3.0 & 3.2	3.8 & 4.0	0	-	-	-

The dimensions of the ostia were not measured if no trunk was present (these were cases of divided ostium, observed in 12 dogs). Normal right ostia were not significantly different in size than right ostia with a small accessory ostium (P = 0.750). Ostia of the LCA were significantly larger than ostia of the RCA (P < 0.001) (Fig. 8, Table 1) and this difference was evident regardless of the body weight of the dog (Fig. 9). The diameter of normal ostia did not differ significantly between the sexes (P = 0.605 for LCA and P = 0.671 for RCA). The diameter of normal ostia was significantly positively correlated with the body weight ($R_s = 0.73$ for LCA and $R_s = 0.66$ for RCA) (Fig. 9).

Discussion

As previously mentioned, the location of the coronary ostia in the area of the aortic sinuses was analysed in various animal species. The location of the structures was assessed using the method proposed by Cavalcanti *et al.* (14), which has been applied both in human and veterinary medicine in domestic cats (3), sheep and swine (35), and equines (36). In the present study, the ostia was most commonly located below the intercommissural line (type I). This type of ostium location was found to be the second most common in cats (3). It is noteworthy that in this species, both ostia were most frequently located on the intercommissural line (type II): in the case of LCA in 42 individuals (65%), and RCA in 43 (66%) (3). In both dogs and cats, the least common location of the coronary ostia was above the intercommissural line (type III) (3).

The location of the coronary ostia was symmetrical in only 44/91 dogs (48%). In contrast, similar observations showed symmetrical positions in most cats (50/65; 77%) (3), horses (45/70; 64%) (36), and sheep (42/58; 72%) (35). Symmetry in a minority of subjects was also observed in pigs: only 27% of these animals had such coronary ostia (16/60) (35).

In veterinary medicine, studies conducted on heart muscles have revealed differences in both morphology and the number of the main coronary vessels between animal species. Interestingly, our present findings indicate that 36/91 dogs showed variations in the structure of at least one of the coronary ostia, with the RCA being more frequently affected. In 65 examined cats such variations in the main coronary ostia or the presence of accessory ostia were found in 13 individuals (20%), with only 3 demonstrating changes in both ostia (3).

In 81 of the studied dogs (89%), the left coronary artery began with a single, normally formed ostium located in the area of the aortic sinus of the left semilunar leaflet. A similar study showed such regularity in 47/48 domestic cats (98%); however, in one cat, an independent ostium of the paraconal interventricular branch and the left circumflex branch was found in the area of the aortic sinus of the left semilunar leaflet (4). In the present study, this variation was identified in two dogs. Similar observations in this species were described by Büll and Martins (12) in 4/30 dogs (13%); however, Noestelthaller *et al.* (31) reported only one such case in a study of 20 domestic dogs. In the present study, the common trunk was found to be absent in 8/91 dogs (9%). This morphological variation was recorded in only 2/65 domestic cats (3), and a similar variation in 5/27 European bison (6). Noteworthy is the fact that in the studied dogs, no accessory ostia were found in the vicinity of the main ostium of the LCA.

In over half of the dogs in the present study (59/91 dogs, 65%), the ostium of the RCA had normal structure. The most common variation was the presence of an accessory ostium adjacent to the main ostium of the RCA, which was observed in 28 dogs (31%). The literature also reports the existence of an accessory coronary artery (*a. coronaria dextra accessoria*) which rarely occurs in dogs. It begins in the aortic sinus of the right semilunar leaflet and runs very close to the main ostium of the coronary vessel (16). Studies on European bison confirmed the presence of variants in the structure of the RCA in 13/14 individuals. Most commonly, these involved single or double accessory ostia located close to the ostium of the RCA (6). Observations by Pereira *et al.* (35) confirm the presence of accessory ostia in 9% of horses (36), 19% of sheep, and 10% of swine.

Numerous studies on coronary artery ostia have also been conducted in humans. Sirikonda and Sreelatha (41) found the ostia of both coronary arteries to have normal structure in 71% of patients, whereas the presence of a third coronary artery was found in 19% of patients. It is generally assumed that coronary artery anomalies are relatively rare, occurring in about 1% of patients. In most cases, they affect the LCA (28, 40). However, this is not confirmed by findings from veterinary medicine. The presence of a double RCA was described by Harikrishnan *et al.* (18).

In human medicine, the morphometry of particular elements of the aortic valve and coronary ostia is clinically important for preventive and repair studies, as evidenced by previous findings (10, 13, 14, 21, 22, 23, 25, 26, 37, 38, 42, 44).

Most human medicine reports on the morphometry of the coronary ostia find that the left coronary ostium is larger than the right (10, 14, 21, 23, 25, 42). Similar observations apply to coronary ostia in various animal species, including dogs as in our study. In domestic cats the left coronary ostium has a larger surface area than that of the right coronary ostium (4). Similarly, the mean diameter of the LCA has been reported to be greater than that of the RCA in donkeys (34), crab-eating macaques (43), green monkeys (30), and adult European bison (6).

As previously mentioned, many publications and specialised textbooks include descriptions and figures relating to the cardiac vascularisation of various species of domestic animals (1, 2, 8, 24). Particularly noteworthy are articles on the heart vascularisation in dogs (5, 11, 12, 16, 31); however, studies on coronary vascular morphometry in this species have only involved measurements of the main trunks of the coronary arteries (31).

In the studied dogs the left and right coronary ostia were located in corresponding aortic valve sinuses. The left coronary ostia were most often located below the intercommissural line (type I), while the right coronary ostia were equally often below and on the intercommissural line (types I and II, respectively). Morphological variations in the structure of the coronary artery ostia occur in approximately 40% of dogs, and the most common variation is the presence of an accessory ostium near the ostium of RCA. Our present findings expand the knowledge of morphology and morphometry of the aortic valve and the initial segments of the coronary arteries in dogs, and can be used for developing standards for veterinarians in clinical practice. Recent advancements in diagnostic imaging and cardiac surgery have revealed a pressing need for detailed knowledge of heart vascularisation.

Conflict of Interests Statement: The authors declare that there is no conflict of interests regarding the publication of this article.

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Animal Rights Statement: Under applicable Polish law, the use of *post-mortem* animal tissues does not require the approval of the Ethics Committee.

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