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Dominance or balance? Revisiting the coronary arteries of the domestic cat

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ABSTRACT. Studies on the behavior of coronary arteries were developed in several species to elucidate variations in their distribution and their morphofunctional correlations, such as the types of irrigation and possible risks of infarction. With the increased frequency of domestic felines in the clinical routine of small animals, requiring the specialization of professionals capable of knowing and considering the morphological differences for a more assertive clinical diagnosis, this study aimed to identify the origin and distribution of coronary arteries in domestic cats. Twenty-nine specimens of domestic cats, fifteen females, and fourteen males, were fixed in a 10% formaldehyde solution, injected with liquid latex stained with a synthetic dye, placed in a 10% formaldehyde solution for at least seven days, and then dissected. The determination of the coronary dominance pattern was based on the origin of the subsinuous interventricular branch defined as right, left, or balanced dominance. The dominance pattern in domestic cats was determined as balanced (69%) and left (31%), contrary to the current literature for animal anatomy. The presence of anastomosis between the coronary arteries and the myocardial bridge was also observed in some individuals. Our results reinforce the existence of interspecific particularities in domestic carnivores. In this context, the description of the coronary arteries in domestic cats contributes to the applied animal anatomy since the understanding of the vessels that nourish the myocardium allows for a more assertive anatomopathological analysis of the species.

Keywords: animal anatomy; carnivores; heart; coronary circulation; feline.

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Introduction

In Brazil and worldwide, cats are among the most popular domestic animals (Little, 2016), with a significant growth of these animals in the clinical routine (Stocco et al., 2021). However, some reference textbooks in teaching Animal Anatomy provide information sometimes inaccurate since they tend to generalize the morphological aspects of dogs and cats under the name of domestic carnivores (Dyce, Sack, Wensing, & Singh, 2019; König & Liebich, 2021).

The main organ of the cardiovascular system is the heart, which consists mainly of cardiac muscle called myocardium. Surrounded by the pericardium, it lies in the mediastinum of the thoracic cavity (Barone & Simoens, 2011; Dyce et al., 2019; König & Liebich, 2021). Highly irrigated, the receipt of this blood supply is the responsibility of coronary arteries originating from two of the three sinuses over the semilunar valves located in the aortic bulb (Dyce et al., 2019; König & Liebich, 2021).

The left is usually the largest among the coronary arteries, arising over the left semilunar valve and reaching the coronary sulcus, which runs between the left atrium and the pulmonary trunk, being divided almost immediately. The paraconal interventricular branch occupies the groove with the same name, which leads the pulmonary trunk to the apex of the heart. Following the coronary sulcus, the trunk continues as a circumflex branch towards the atrial surface, which may end near the origin of the subsinuous interventricular sulcus (swine and horses) or even occupy it, as in ruminants and carnivores (Evans & De Lahunta, 2013; Dyce et al., 2019).

According to Schelesinger (1940) and Silva, Marinho, Araújo, Carvalho, and Cavalcanti (2019), concerning coronary anatomy in humans, individuals who have a left dominance pattern are considered a pathologically

important group because they suffer from arteriosclerosis and infarction. However, individuals who have a balanced pattern when suffering a heart infarction would rarely result in death.

The study of coronary anatomy has been conducted in several species in the domestic and wild scope to contribute information both from the point of view of descriptive and applied anatomy, as well as for reflections on phylogenetic relationships on the zoological scale (Borelli, 2014; Barszcz et al., 2019; Barszcz et al., 2020).

In domestic carnivores (dogs and cats), coronary dominance is commonly described as left-sided (Biasi, Borelli, Benedicto, Pereira, & Favaron, 2012; Borelli, 2014; Dyce et al., 2019; Viotto-Souza et al., 2023; König & Liebich, 2021). However, the balanced pattern predominates in the neotropical species of the suborder Feliformia (Mengue et al., 2018; Viotto-Souza et al., 2023).

Therefore, the growing demand for increased information about domestic cats requires the specialization of professionals capable of knowing and considering the morphological differences for a more assertive clinical diagnosis. This study aimed to describe the origin and distribution of coronary arteries in cats to contribute information to the field of comparative animal anatomy.

Material and methods

This study was submitted and approved by the Animal Research Ethics Committee (CEUA) from the *Universidade Federal do Acre* under protocol 23107.013524/2021-19.

For this study, 29 hearts of adult Brazilian shorthair cats, 15 females, and 14 males, were used, with no confirmed cause of death. The specimens came from Veterinary Clinics, the Zoonosis Center of Rio Branco, and the Teaching and Research Laboratory in Morphology of Domestic and Wild Animals at the *Universidade Federal Rural do Rio de Janeiro* (UFRRJ) without macroscopic signs of cardiac changes.

The cadavers were positioned on right lateral decubitus, and the thoracic cavity was opened by an incision from the fifth to the eighth rib. The thoracic aorta was dissected "*in situ*" and cannulated for lavage of the vascular system with saline solution and fixation with 10% formaldehyde. Immediately afterward, the vascular system was filled with Petrolax S-65 (*Refinaria Duque de Caxias* – REDUC/Petrobrás, Duque de Caxias, Rio de Janeiro, Brazil) stained with dye xadrez®. Subsequently, animals were placed in low-density polyethylene boxes with a capacity of 500 L containing a 10% formaldehyde solution to complete the latex fixation and polymerization process, where they remained for at least seven days. After fixation, animals were washed in running water and had their hearts collected by transection of the base vessels, identified, and separated by sex.

The nomenclature was based on the Nomina Anatomica Veterinaria (ICVGAN, 2017), and the data collected were presented in absolute frequency and simple percentage. Photomacrographs of the hearts were performed using a DSLR Canon EOS 2500, Rebel SL 3. 24MP with lens CC 18-55m.

The coronary dominance pattern was established as left, right, or balanced, using the subsinuous interventricular branch origin pattern method, following Scansen (2017) and aspects used by Mengue et al. (2018) and Viotto-Souza et al. (2023). Thus, left or right dominance is characterized when the left or right coronary arteries are solely responsible for originating the paraconal and subsinuous branches. The balanced pattern (balanced) was associated with two aspects: each coronary artery gave rise to an interventricular branch, that is, the left gave rise to the paraconal interventricular branch, and the right, the subsinuous one; the total number of branches originating from each coronary artery was similar.

The chi-square test was applied to check the relationship between the sexes and the two patterns of coronary arrangement, considering a significant difference when the p-value < 0.05.

Results and discussion

Anatomical studies represent crucial tools for solving questions related to understanding the functioning of morphological structures and their interactions and helping to understand the biology and evolution of species (Assunção et al., 2019). However, dogs and cats have morphological differences that are sometimes disregarded in some reference textbooks in veterinary anatomy (Dyce et al., 2019; Konig & Liebich, 2021). The recognition of such differences is of paramount importance due to the increasing degree of demand for feline medicine (Stocco et al., 2021).

The dissection of the 29 hearts of cats (15 females and 14 males) allowed the identification of two types of coronary arrangement (Table 1): left and balanced dominance.

Table 1. Absolute frequency and simple percentage of coronary dominance in hearts of domestic cats.

Coronary Arrangement	Females (n = 15)	%	Males (n =14)	%	Total (n = 29)	%
Left dominance	5	33%	4	29%	9	31%
Balanced pattern	10	67%	10	71%	20	69%

Among the 29 hearts analyzed (Figure 1), 69% (n = 20) showed a balanced pattern, and 31% (n = 9) left coronary dominance, corroborating the findings in 23 neotropical wild felids dissected by Viotto-Souza et al. (2023). Left dominance was present in about 29% (n = 4) of males and 33% (n = 5) of females, while a balanced pattern was observed in 71% (n = 10) of males and 67% (n = 10) of females. There was no significant difference in coronary dominance between sexes (p = 0.78).

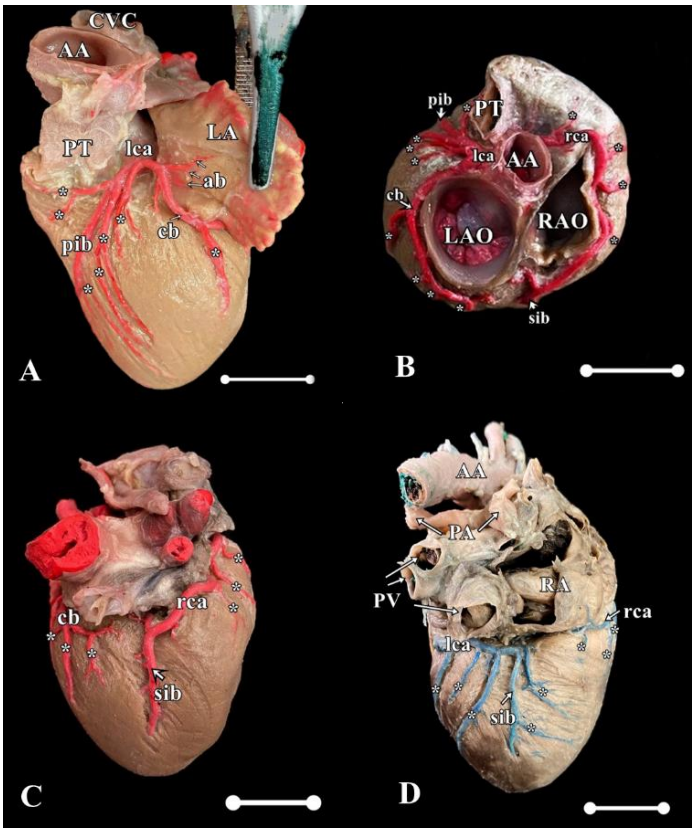

Figure 1. Photomacrographs showing the coronary arteries of domestic cats on the auricular (A), dorsal (sectioned atria and basal vessels) (B), and atrial views (C and D). A: CVC – cranial vena cava, AA – aorta artery, PT – pulmonary trunk, LA – left atrium, lca – left coronary artery, cb – circumflex branch of the left coronary artery, ab – atrial branches, pib – paraconal interventricular branch, * ventricular branches. B: PT – pulmonary trunk, AA – aorta artery, LAO – left atrioventricular ostium, RAO – right atrioventricular ostium, lca – left coronary artery, pib – paraconal interventricular branch, cb – circumflex branch of the left coronary artery, rca – right coronary artery, sib - subsinuosal interventricular branch, * ventricular branches. C: cb - circumflex branch of the left coronary artery, rca - right coronary artery, sib - subsinuosal interventricular branch, * ventricular branches. D: AA – aortic arch, PA – pulmonary arteries, PV – pulmonary veins, RA – right atrium, rca – right coronary artery, lca – left coronary artery, sib – subsinuosal interventricular branch, * ventricular branches. Scale bar: 1cm.

The left coronary artery originates in the left sinus of the aortic bulb in all hearts and follows the left coronary sulcus, dividing into a paraconal interventricular branch and a left circumflex branch, corroborating the descriptions for carnivores (Dyce et al., 2019; Konig & Liebich, 2021). This description has also been reported in cats by Monfared, Moosavi, and Bazdar (2013) and in *Nasua nasua* (Linnaeus, 1766) by Viotto-Souza et al. (2023).

The paraconal interventricular branch (PIB) emerged from the left coronary artery accompanying the groove of the same name on the auricular surface in the left ventricle; at certain times, it reached the apex of the heart, as observed by Viotto-Souza et al. (2017) in 5 of the 6 felid's hearts from *Puma concolor*. This branch gave rise to an average of 5.4 branches, like the study by Viotto-Souza et al. (2023), who observed an average of 6.4 branches in Neotropical felids, and Monfared et al. (2013) an average of 5.7 branches in domestic cats. The presence of myocardial bridges was observed in this branch in some samples, as reported by Ávila, Machado, Gerbasi, and Oliveira (2009) in paca hearts.

The left circumflex branch (CB) emerged from the left coronary artery, located in the coronary sulcus, and gave rise to an average of 4.6 branches. In cattle, Correia-Oliveira, Hernandez, and Abidu-Figueiredo (2013) described an average of 11.91 branches in females and 11.65 in males, highlighting no relevant difference between the sexes. Yuan (2009) explained that these thin branches supply blood to the margin of the posterior wall of the ventricle and atrioventricular junction. This branch may terminate near the origin of the subsinuous interventricular branch (SIB) in balanced patterns or continue in the groove of the same name and give rise to the SIB in left dominance patterns. In this branch, the presence of a myocardial bridge was also observed in three samples.

The subsinuous interventricular branch (SIB) appeared continuously after the left circumflex branch when the dominance was of a left pattern or emerged from the right coronary artery, characterizing a balanced coronary dominance. It gave rise to an average of 2.59 branches, which may or may not reach the apex of the heart. Anastomosis was found between PIB and SIB in 3 hearts. In one individual, anastomosis was observed between the left circumflex branch and the right coronary artery, as reported in domestic dogs (Bull & Martins, 2002) and some canids, felids, mustelids, and neotropical raccoons (Viotto-Souza et al., 2023).

In some neotropical canids, Viotto-Souza et al. (2023) observed that the SIB originated from the CB, unlike in neotropical felids, where the right coronary artery itself, after traversing the coronary sulcus gave rise to the SIB. In wild Neotropical specimens, a left dominance in the suborder Caniformia and a balanced pattern in the suborder Feliformia was suggested.

The right coronary artery [originated from the right sinus (36%) or the cranial surface (64%) of the aortic bulb] followed between the right atrium and the pulmonary trunk and was distributed through the coronary sulcus, which gave rise to the SIB in 69% of the samples. The RCA gave rise to an average of 5.6 ventricular branches, which seems consistent with descriptions for other carnivorous species, such as *L. guttulus*, from 4 to 6 branches (Mengue et al., 2018), domestic cats 3.6 branches (Monfared et al., 2013), and domestic dogs, 4.1 branches (Oliveira, 2011).

When the coronary circulation was characterized as balanced (69%), the left coronary artery was participating, giving rise to the PIB and the CB, and the right coronary artery, giving rise to the SIB. Borelli (2014) reported a balanced dominance of 18.3% in 60 hearts analyzed. Regarding the study of Viotto-Souza et al. (2017), all six specimens of *P. concolor* showed a balanced pattern. This is also similar to the results observed by Mengue et al. (2018) in *L. guttulus*, differing from the pattern found in most carnivorous specimens.

As for the left coronary dominance (31%), the left coronary artery gave rise to PIB, CB, and SIB, while the right coronary artery followed the coronary sulcus, giving rise to small ventricular branches until they disappeared on the atrial face, close to the subsinuous branch. In this type of dominance, the contribution to the ventricular vascularization of the right coronary artery was poorly developed, as observed by Biase et al. (2012) in cat hearts, Pinheiro, Branco, Pereira, and Lima (2014) in anteater, and Viotto-Souza et al. (2023) in carnivores.

Although the literature reports the left dominance pattern in carnivores and ruminants, some species differ from this description. The left dominance pattern was described for crossbred cattle, goats, and dogs (Moura-Júnior et al., 2009; Pinto-Neto et al., 2009; Oliveira et al., 2011; Correia-Oliveira et al., 2013; Correia-Oliveira, Moraes, Gomes, Palhano, & Abidu-Figueiredo, 2014). However, in the case of felines, such as *L. guttulus* (Mengue et al., 2018), *Puma concolor* (Viotto-Souza et al., 2017), *Panthera tigris* (Perez & Lima, 2007), and *Felis catus* (Borelli, Fernandes-Filho, & Ferreira, 1971; Biase et al., 2012; Borelli, 2014), a pattern of left and balanced dominance was found, with left dominance being the most common.

The International Committee on Veterinary Gross Anatomical Nomenclature [ICVGAN] (2017) points out that the subsinuous interventricular sulcus in domestic cats can be occupied by both the right coronary artery and the circumflex branch of the left coronary artery and this information was described by Nickel, Schummer, and Seiferle (1981) and Hudson and Hamilton (2017). Nevertheless, Nickel et al. (1981) point out that occupation of the subsinuous interventricular sulcus by the right coronary artery is not frequent. Although the studies by Biasi et al. (2012) and Borelli (2014) regarding the vascular distributions in the ventricles of hearts of domestic cats show a balanced pattern in some specimens of their samples, the same authors assume that the circulation is predominantly left-dominant, corroborating Dyce et al. (2019) and König & Liebich (2021). However, recent studies with species of the family Felidae (Viotto-Souza et al., 2017); Mengue et al., 2018; Viotto-Souza et al., 2023) have shown that in most specimens used in their respective studies, the balanced pattern was the most frequently observed. These findings were similar to the results of our research.

In the family Felidae, there are cases of left and balanced pattern dominance, according to the phylogenetic proximity between the species, respecting the pattern by lineage. Despite coming from different biomes, the balanced pattern was consistent in five species, among the seven belonging to the lineage "ocelot." The same was observed in two puma lineage species (Viotto-Souza et al., 2023).

The coronary anatomy is remarkably diverse, although the coherent paths, origin, and ramifications are less regular. These differences can be found in other studies, determined due to geographic region, the number of hearts studied, and the time of year (Silva et al., 2019).

The study of the ventricular branches of these arteries is essential due to its clinical application during the execution and interpretation of some exam methods and the planning and execution of treatments for cardiovascular diseases (Schelesinger, 1940; Pino, Riffo, Vargas, & Vargas, 1987). Any alteration that compromises the functioning of arterial vessels of the myocardium can cause cardiovascular diseases (Boapassa, 2012), among which ischemia is the most common, caused by partial or total obstruction of blood flow (Farber, Chien, & Mittnnacht, 1981).

Conclusion

The balanced coronary dominance pattern was the most frequent in domestic cats of both sexes, differing from the left coronary dominance widely reported for domestic carnivores. The results found here reinforce the existence of interspecific particularities in domestic carnivores. In this context, the description of coronary arteries in domestic cats contributes to Comparative Animal Anatomy and the field of applied anatomy since the understanding of the vessels that nourish the myocardium can support more assertive anatomopathological analysis for this species.

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