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Myocardial bridges and coronary distribution in dairy cattle from Brazil Northeast. Pontes miocárdicas e distribuição coronariana em bovinos leiteiros do Nordeste brasileiro.

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Abstract

This study evaluated the distribution and possible variations of the coronary arteries and the presence of myocardial bridges in dairy cattle from Northeastern Brazil. Thus, healthy hearts were analyzed according to many variables. Left coronary artery originate the *rami paraconalis*, *circumflexus et subsinuosus*. *Ramus subsinuosus* and right coronary artery showed a short subepicardial path. Lengths of the main branches showed statistical differences only in relation to age group and weight of the animal. Myocardial bridges had a prevalence of 55% and were more frequent over the *ramus paraconalis*. Veterinary medicine is able to provide experimental models to expand the necessary study to understand pathophysiology and clinical relevance of the bridges.

Keywords: Blood circulation. Myocardium. Cardiovascular system. Bovine.

Resumo

Este estudo avaliou a distribuição e possíveis variações das artérias coronárias e a presença de pontes miocárdicas em bovinos leiteiros do Nordeste do Brasil. Assim, corações saudáveis foram analisados de acordo com muitas variáveis. A artéria coronária esquerda origina os *rami paraconalis*, *circumflexus et subsinuosus*. O *ramus subsinuosus* e a artéria coronária direita apresentavam trajeto subepicárdico curto. Os comprimentos dos ramos principais apresentaram diferenças estatísticas apenas em relação à faixa etária e ao peso do animal. As pontes miocárdicas tiveram prevalência de 55% e foram mais frequentes sobre o *ramus paraconalis*. A medicina veterinária é capaz de fornecer modelos experimentais para expandir o estudo necessário para entender a fisiopatologia e a relevância clínica das pontes.

Palavras-chave: Circulação sanguínea. Miocárdio. Sistema cardiovascular. Bovino.

Introduction

According to the OECD-FAO (Food and Agriculture Organization of the United Nations) Brazil stands out in world livestock production and, together with the United States and the European Union, will be responsible for approximately 60% of the world meat exports in 2029 (OECD-FAO, 2020). Substances necessary for the production of meat and milk (nutrients, hormones, etc.) circulate through the blood to the muscles and the udder, respectively (GETTY, 1986; DYCE et al., 2010). The circulatory system, therefore, is directly related to animal production.

The heart is compared to a large and powerful pump that drives blood to all tissues in the body. Thus, the heart, similar to any other tissue, also needs to have its own blood supply, receiving the equivalent of 15% of the cardiac output of the left ventricle (DYCE et al., 2010). The right and left coronary arteries, which emerge right after the aortic bulb, are responsible for this distribution, occupy the *sulcus coronarius* and present different paths and distributions according to each species (GETTY, 1986; FRANDSON et al., 2017).

According to König et al. (2011), angiology is the branch of science dedicated to the study of the shape, structure, topography and functioning of blood vessels. Thus, knowing and better understanding the distribution of cardiac vessels, especially coronary arteries and their branches, allows a better understanding of the blood supply in this organ, as well as possible pathologies that can be established on these, such as myocardial infarction and atherosclerosis (SIERVULI et al., 2014).

Myocardial bridge is the term used to describe the muscle bands that overlap the segments of the epicardial coronary arteries (ZHAO et al., 2019). A potential relationship is reported between myocardial bridges and some cardiac changes such as ischemia (TARANTINI et al., 2016), myocardial fibrosis (BRODSKY et al., 2008) and coronary spasm (TERAGAWA et al., 2003).

Studies on the variation in the anatomical distribution of the coronary arteries and myocardial bridges are still scarce in dairy cattle from northeastern Brazil (RODRIGUES et al., 1999; CORREIA-OLIVEIRA et al., 2013, 2014). Therefore, given the importance of this study, this research evaluated and described the path and possible variations in the distribution of coronary arteries and the presence of myocardial bridges in cattle from a dairy region in northeastern Brazil.

Material and methods

All methodology adopted for the development of the present research was submitted and approved by the Ethics Committee on the Use of Animals (CEUA) of the Federal Rural University of Pernambuco (UFRPE), Recife-PE, under protocol number 028/2019.

Twenty-two hearts of 17 females and five bovine males aged between two days and nine years, weighing between 30 and 620 kg were studied. The animals came from necropsies performed at the Animal Pathology Sector of the Animal Anatomy and Pathology Laboratory (LAPA) at UFAPE and sent to the Animal Anatomy Sector of the same laboratory. Age, gender, weight and breed were recorded on the necropsied animal's record. The breeds recorded in the chart were Holstein (eight), Gir x Holstein (five), other crossbred (seven), Brown-Swiss (one) and Guzerá (one). The main cause of death was related to locomotor problems (fractures, traumas, muscle rupture, among others) and reproductive problems (uterine rupture and torsion, dystocia).

The hearts were removed by sectioning the vessels at the base. Subsequently, the specimens were washed, and the clots removed before being fixed in a 10% formaldehyde solution, where they remained until dissected. Then, the coronary arteries and their branches were evidenced from the origins in the aorta, with the use of appropriate dissection instruments, until their macroscopically visible terminations.

The main branches of the coronary arteries and whenever myocardial bridges were observed, the lengths were measured with the aid of a digital caliper and a flexible ruler, as well as the location (topography and vasculotopy) of each of them in each studied heart was recorded and documented.

All information obtained was recorded and reported using the Veterinary Anatomical Nomenclature (INTERNATIONAL, 2017).

Measurements of the length of the branches of the coronary arteries and the bridge of the bovine *ramus paraconalis* were tabulated in an Excel spreadsheet. Initially, a logarithmic transformation was carried out in order to homogenize the variances of the groups. After that, the normality of the data was tested by the Shapiro-Wilk test. Then, a comparison was made of the data obtained when measuring branches of the coronary arteries and the bridge of the *ramus paraconalis*, with dependent variables: sex, breed, age and weight. For parametric analysis, Student's t test and Scheffe test were used and for non-parametric analysis, Kruskal Wallis and Mann-Whitney tests were used. Subsequently, a correlation analysis was performed between the length of the structures using Pearson's or Spearman's Correlation (depending on the distribution of the variables) (SAMPAIO, 2015). The IBM SPSS Statistics 23.0 program was used to perform the aforementioned statistical calculations. The level of significance was set to 5.0% for all analyses.

Results

Left coronary artery

It originated on the left side of the aorta and after a short course, in the *sulcus coronarius*, it was divided into two branches, the *ramus interventricularis paraconalis* (*ramus paraconalis)* and the left *ramus circumflexus*. The left *ramus circumflexus* continued in the *sulcus interventricularis subsinuosus*, where it became known as the *ramus interventricularis subsinuosus (ramus subsinuosus)*. An extra branch (diagonal branch) was found in four hearts, with the same origin as the *rami paraconalis* and *circumflexus*, which runs above the left ventricle, on the auricular surface (Figure 1A).

The *ramus paraconalis* coursed through the *sulcus paraconalis* and emitted one to two subepicardial branches, mainly towards the left ventricle, although in a few cases it was also observed over the right ventricle. The *ramus paraconalis* deepened in the myocardium close to the apex of the heart. In only one case did this occur a few centimeters (3.7 cm) from the origin of the branch. On the contrary, in most of the analyzed hearts, the *ramus subsinuosus* runned a short path and soon entered the myocardium (Figure 1B), justifying subepicardial lengths much smaller than the *ramus paraconalis*. Even so, the short *ramus subsinuosus* also emitted a subepicardial branch, found in four specimens.

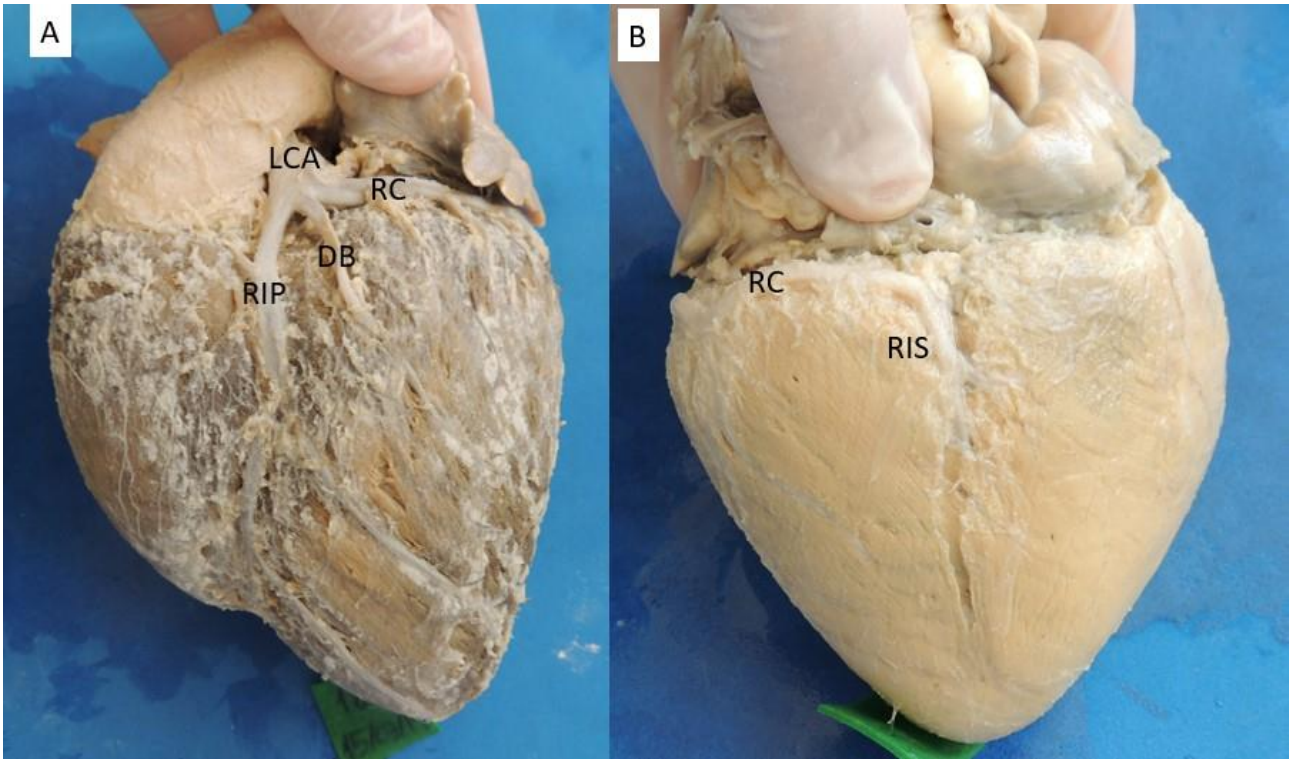

Figure 1 - A. Auricular surface of the bovine heart. Note the bifurcation of the left coronary artery in *rami interventricularis paraconalis* (RIP) *et circumflexus* (RC) and among them the emergence of the diagonal branch (DB). B. Bovine heart atrial surface. The *ramus interventricularis subsinuosus* (RIS) originates from the *ramus circumflexus* (RC), which courses a short distance before going deeper into the myocardium. Source: the authors.

The left *ramus circumflexus* surrounded the *sulcus coronarius* to the *sulcus subsinuosus* and emitted subepicardial branches still on the auricular surface and/or in the region between the auricular and atrial surfaces (marginal region, *ramus intermedius*) (Figure 2A). When the branches were located in the marginal region, they presented themselves as two long branches with a certain parallelism (Figure 1B) or a branch that soon divided into several others, directed to the margin and the apex.

Gender and breed did not influence the measures of length of the branches of the left coronary artery, according to the statistical analysis (p <0.05) observed in Tables 1 and 2.

Table 1 - Means and standard deviation of the length of the branches of the bovine coronary arteries and the *ramus paraconalis* bridge by sex.

	Sex	
Structure	**Male**	**Female**[2]
Right coronary artery	9.20 ± 7.10	9.20 ± 2.18
Ramus subsinuosus	3.56 ± 2.20	3.81 ± 2.70
Ramus paraconalis	12.90 ± 3.84	16.31 ±3.88
Ramus circunflexus	13.63 ± 3.88	15.53 ± 3.57
Ramus paraconalis bridge	3.66 ± 2.29	2.16 ± 0.98

[1] n=5; [2] n=15; different letters on the same line indicate a difference by Student's t test ($p < 0.05$)

Table 2 - Mean and standard deviation of the length of the branches of the bovine coronary arteries and the *ramus paraconalis* bridge by breed.

	Breed	
	Crossbred[1]	**Purebred**[2]
Right coronary artery	8.30 ± 2.18	10.25 ± 3.78
Ramus subsinuosus	2.20 ± 0.69	5.65 ± 4.34
Ramus paraconalis	14.30 ± 4.47	16.27 ± 3.63
Ramus circumflexus	13.22 ± 4.45	17.00 ± 4.29
Ramus paraconalis bridge	2.36 ± 0.84	3.05 ± 2.30

[1] n=11; [2] n=9; different letters on the same line indicate a difference by Student's t test ($p < 0.05$)

On the other hand, when the length averages were compared in terms of age (Table 3) and weight (Table 4), significant differences were found (p <0.05). The *rami paraconalis et circumflexus* showed greater lengths in older animals (above 18 months). Animals weighing less than 100 kg obtained shorter lengths in the *rami subsinuosus et circumflexus*, while the *ramus paraconalis* was shorter in individuals weighing up to 300 kg.

Table 3 - Mean and standard deviation of the length of the branches of the bovine coronary arteries and the *ramus paraconalis* bridge by age.

	Age	
Structure	**under 18 months**	**above 18 months**
Right coronary artery**	8.08 ± 2.33	10.60 ± 3.37
*Ramus subsinuosus***	3.80 ± 4.32	3.65 ± 1.83
*Ramus paraconalis***	12.94 ± 3.99^{A}	17.97 ± 1.63^{B}
*Ramus circunflexus***	12.04 ± 3.81^{A}	18.47 ± 2.32^{B}
Ramus paraconalis bridge*	2.08 ± 0.69	3.40 ± 2.16

[1] n=12; [2] n=8; *Student's t test; **Mann-Whitney test; different letters on the same line indicate statistical difference ($p < 0.05$)

Table 4 - Means and standard deviation of the length of the branches of the bovine coronary arteries and the *ramus paraconalis* bridge by weight.

	Weight		
Estruturas	**under 100 kg**[1]	**100-300 kg**[2]	**above 300 kg**[3]
Right coronary artery**	7.33 ± 0.91^{A}	13.52 ± 6.27^{B}	12.80 ± 3.17^{B}
*Ramus subsinuosus***	2.44 ± 1.13^{A}	5.02 ± 2.26A^{B}	6.71 ± 3.33^{B}
*Ramus paraconalis***	11.21 ± 0.75^{A}	12.80 ± 7.08^{A}	19.35 ± 3.35^{B}
*Ramus circumflexus***	10.70 ± 0.97^{A}	16.27 ± 5.10^{B}	19.01 ± 1.48^{B}
Ramus paraconalis bridge*	2.37 ± 0.26^{A}	1.10 ± 0.00^{A}	3.35 ± 2.23^{A}

[1] n=7; [2] n=4; [3] n=9; * Parametric analysis; ** Non-parametric analysis; different letters on the same line indicate statistical difference ($p < 0.05$)

Right coronary artery

The right coronary artery originated on the right side of the aorta, it coursed through the space between the right auricle and the pulmonary trunk until it reached the *sulcus coronarius*, where it proceeded towards the auricle (Figure 2B). From that point on, it either entered the myocardium or extended until close to the *sulcus subsinuosus* and may emit subepicardial branches towards the right ventricle on the atrial surface or in the right marginal region, in some specimens.

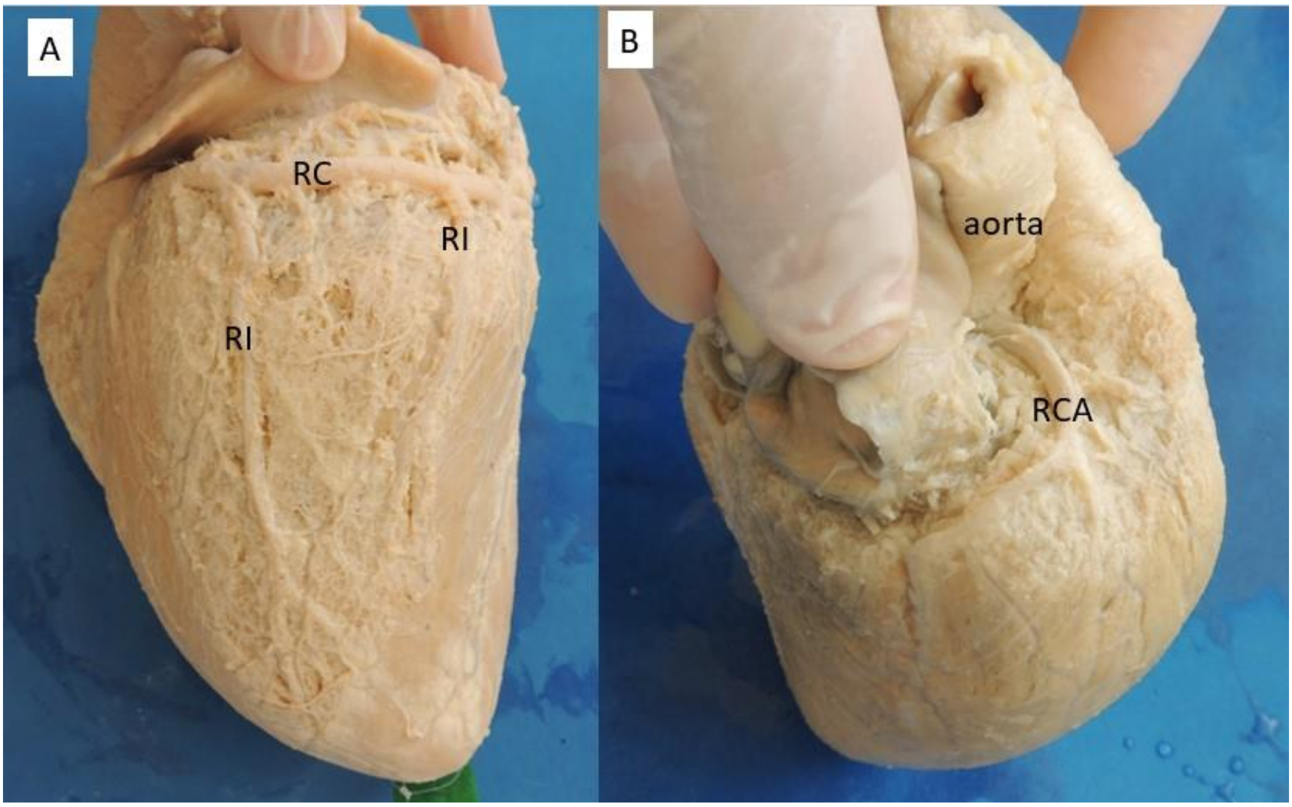

Figure 2 - A. Left margin of the bovine heart. In this region, the *ramus circumflexus* (RC) can send the *ramus intermedius* (RI), generally parallel. B. The right coronary artery (RCA) after emerging from aorta follows the *sulcus coronarius* and sends small branches. Source: the authors.

There was no statistical difference ($p < 0.05$) regarding sex, breed and age range in the length of the right coronary artery (Tables 1, 2 and 3). Individuals over 100 kg had significantly greater lengths of this vessel ($p < 0.05$), as shown in Table 4.

There were positive and significant correlations ($p < 0.05$) between the lengths of all branches of the left coronary artery and the right coronary artery, with the highest correlations ($p < 0.001$) found between the right coronary artery and the *ramus paraconalis* and between the *ramus paraconalis* and the left *ramus circumflexus* (Table 5).

Myocardial bridges

Myocardial bridges had a prevalence of 55%, were found in 12 of the 22 dissected hearts. When present, there were one to two bridges in each heart and the majority was over the *ramus paraconalis* (Figure 3A). Only two specimens were over the *ramus subsinuosus* (Figure 3B) and in one heart there were bridges in both branches. When observed only over the *ramus subsinuosus*, the two hearts had two bridges over the same vessel, although one was visually thinner in width and thickness than the other.

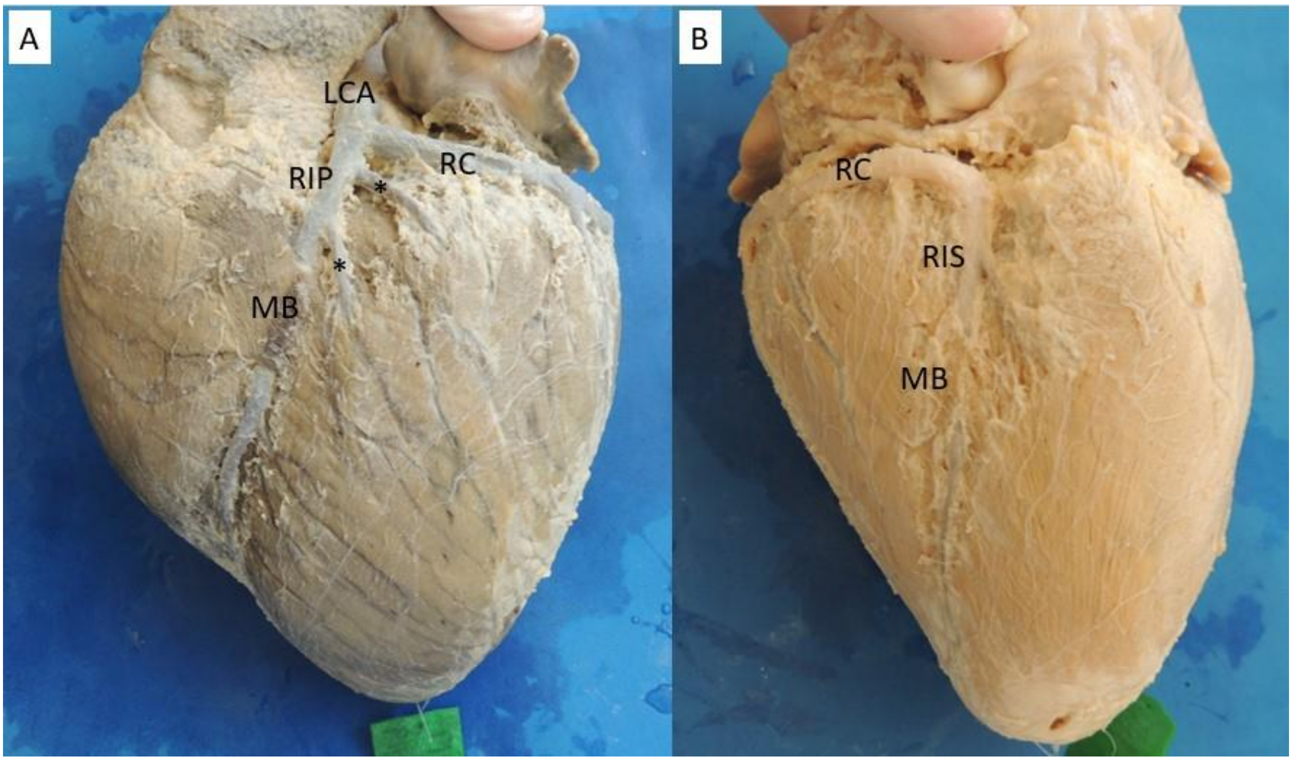

Figure 3 - A. Bovine heart auricular surface. The left coronary artery *ramus interventricularis paraconalis* presents a myocardial bridge in the middle third, after the emission of two large branches. B. In two specimens, *ramus interventricularis subsinuosus* (RIS) had a myocardial bridge. Source: the authors.

All bridges were found in the region of the middle third of the vessel it covered. No myocardial bridges were observed over the right coronary artery or over the left *ramus circumflexus*. Over a division of the *ramus paraconalis* on the left ventricle, a bridge was found, the only occurrence observed over branches of the main *rami* of the coronary arteries.

There were no statistical differences in the length of the myocardial bridges over the *ramus paraconalis* in all the evaluated items (sex, breed, age and weight). The lengths of the evaluated bridges did not show significant correlation with any of the lengths of the left coronary artery branches or the right coronary artery (Tables 1 to 5).

Discussion

The dairy region of Pernambuco, a northeast state in Brazil, provided the animals for this study, so the main bovine breeds used in this study have such aptitude, such as Holstein and crossbred (Gir x Holstein and others). Although articles dealing with bovine cardiac vascularization are scarce, the most studied breeds are of double aptitude or beef cattle, such as Gir, Guzerá and Indubrasil (SEVERINO; BOMBONATO, 1992), Canchim (SANTOS et al., 2000 and 2011), Nellore (SEVERINO; BOMBONATO, 1992; MARTINS et al., 2008), crossbred (SHINJO et al., 2004;

CORREIA-OLIVEIRA, 2013 and 2014) and half-breed (SEVERINO et al., 1997), which reinforces the importance of the contribution of the current research.

The nomenclature used to describe the studied bovine coronary arteries followed the most recent Nomina Anatomica Veterinaria (INTERNATIONAL, 2017). However, it was noticed that some branches found were not listed in the current official nomenclature, such as the diagonal branch of the left coronary artery and the collateral branches of both coronary arteries. The diagonal branch was previously found (CORREIA-OLIVEIRA et al., 2014) in seven (7/30) crossbred Gir x Holstein cattle. In the studied hearts, four (4/22) had this branch. The literature does not name branches in the right coronary artery in ruminants, citing them only as collateral (GETTY, 1986; CORREIA-OLIVEIRA et al., 2013 and 2014). Martins et al. (2008) also noticed this scarcity of nomenclature to describe the other branches of coronary arteries in cattle and had to rely on other articles to complement the description.

In all hearts described, the left coronary artery gave rise to the *rami paraconalis*, *circumflexus et subsinuosus*, while the right coronary artery was limited to the *sulcus coronarius*, as observed by other authors (BORELLI; FERNANDES-FILHO, 1970; CORREIA-OLIVEIRA et al., 2013). Coronary arterial dominance is determined according to the artery that gives rise to the posterior interventricular artery (SANTOS et al., 2021), which corresponds to the animals' *ramus subsinuosus* in terms of location. These authors described the dominance of human coronary arteries as predominantly right (52.6%) (SANTOS et al., 2021), unlike the studied cattle, which had 100% dominance of the left coronary artery. Of the domestic species, cats can have dominance in any of the coronaries, but it is known that ruminants and canines have left dominance, and pigs and horses, right (INTERNATIONAL, 2017). However, Borelli and Fernandes-Filho (1970) reported 6 cases (4%) in which the right coronary artery gave rise to the right *ramus circumflexus* and the *ramus subsinuosus* in five cattle of European origin (10%) and one zebu (1%).

No differences were found between the sexes regarding the lengths of the right coronary artery or the branches of the left coronary artery, as well as Correia-Oliveira et al. (2013). Among the measures taken by these authors (CORREIA-OLIVEIRA et al., 2013) in bovine coronary arteries, the similarity in the lengths of the right coronary artery and *rami paraconalis et circumflexus* with the current study stands out, but the authors describe significantly longer lengths for the *ramus subsinuosus*. The cattle from northeastern Brazil showed a short subepicardial path of the *ramus subsinuosus* and only in two hearts did this branch remain superficially beyond the middle third of the *sulcus interventricularis subsinuosus*. It should be noted that in both studies, the animals evaluated had the same aptitude (dairy), age groups consistent and allocated in mountainous geography, with no external reasons at first glance for the difference in myocardial development in this region of the evaluated hearts.

There are records of myocardial bridges in 100% of analyzed hearts (SEVERINO et al., 1997; GULMEZ; SAH, 2021), however, in the current study the existence of this characteristic was demonstrated in 55% of the 22 hearts. In pigs, from a total of 60 hearts, the presence of myocardial bridges was reported in 36.36% of them (BOMBONATO et al., 1994). In humans, bridges were found in 40.3% of the studied hearts, mainly in specimens with left dominance (22.8%) (SANTOS et al., 2021). These authors emphasize that this frequency is not common in humans, and clinically may suggest that bridges may be less frequent in populations with the usual distribution of arterial dominance. The usual dominance in cattle is left, as observed in the current study and by Correia-Oliveira (2014), however, no reports were found on the presence of myocardial bridges in cattle with usual and unusual dominance.

Myocardial bridges have been reported in several species besides human (SANTOS et al., 2021), such as ruminants (CORREIA-OLIVEIRA, 2013, 2014; GULMEZ; SAH, 2021), pigs (BOMBONATO et al., 1994), mules (RIBEIRO et al., 2009), monkeys *Cercopithecus aethiops sabeus* (NIKOLIĆ et al., 2009), among others.

The findings of the present study corroborate with the one that observed the vast majority (94.3%) of bridges over the left coronary artery branches (SEVERINO et al., 1997). In other studies, bridges were described in subdivisions of the main coronary branches in cattle in a significant amount (29 of 106) (SEVERINO et al., 1997), in six pigs (BOMBONATO et al., 1994), and only one bovine presented this characteristic in the current study.

In the evaluated hearts, all myocardial bridges were located predominantly in the middle portion (middle third) of the vessel. Santos et al. (2021) observed the same location in most vessels that had bridges, even more striking in hearts with left dominance. Bridges occur almost exclusively in the middle region of the left anterior descending coronary artery (corresponding to the *ramus paraconalis* of the animals) (ISHIKAWA et al., 2011).

The average length of the bovine myocardial bridges over the *ramus paraconalis* of this study (24.6 ± 15.3 mm) was similar to that found in sheep (24.9 ± 16.1 mm) (GULMEZ; SAH, 2021). In half-breed cattle, the bridges had an average length of 16.2 mm (SEVERINO et al., 1997) and in pigs, 7.5 mm (BOMBONATO et al., 1994)

Most of the myocardial bridges in pigs were found over the *ramus subsinuosus* (BOMBONATO et al., 1994). It is pertinent to take into account the distinct origin of the *ramus subsinuosus* between these two species (in ruminants it originates from the left coronary artery, and in swine, from the right). Likewise, there was a difference regarding the presence of bridges in the *ramus circumflexus*, which were present in pigs (3 on the right and 2 on the left), however, were absent in the present study.

One of the importance of studying the vascularization of the heart is to understand how functional structures are supplied, such as the conduction system. Both coronary arteries provide branches for the sinoatrial node and the trunk of the atrioventricular fascicle, with the right ventricular branch derived from the *ramus subsinuosus* of the left coronary artery and the *rami septales* derived from the right coronary artery being the most frequent vessels of these structures, respectively (MARTINS et al., 2008). Therefore, cardiac angiology research may contribute to the physiological analysis, the interpretation of imaging tests and the clinical and surgical evaluation of the patient (human or animal).

Several authors (ISHIKAWA et al., 2011; NASR, 2014; ZHAO et al., 2019) report that in humans, myocardial bridges cause coronary heart disease by two distinct mechanisms, influenced by the anatomical characteristics of the bridge, related to artery compression during cardiac systole and increased coronary atherosclerosis due to stenosis of the artery near the myocardial bridge. They also report that the study of myocardial bridges assists in the treatment decisions of heart disease and in the clinical improvement of the patient. In Canchim cattle, the lesions found before the bridge, in the bridge and in the post myocardial bridge are similar to the lesions that precede the formation of the atherosclerotic plaque, although in the region of the bridge there are smaller lesions than in the other regions (SANTOS et al., 2011). By analogy to the microscopic findings of the pre-bridge coronary arteries, cattle have the same chance of developing atherosclerosis as humans (SHINJO et al., 2004). However, coronary artery diseases resulting from myocardial bridges should not occur in sheep in veterinary practice, as they observed bridges in 100% of the analyzed sheep hearts, with no detected coronary disease (GULMEZ; SAH, 2021).

Myocardial bridges are an interesting area of study, as it is not clear whether they are a pathology, a variation or even a physiological protection strategy for certain clinical conditions (SANTOS et al., 2021). The literature is unanimous regarding the need to extend studies on the topic to understand the pathophysiology and clinical relevance of these bridges. In this way, veterinary medicine will be able to provide experimental models to expand knowledge on the subject.

Conclusion

Dairy cattle coronary arteries may present variation into their branches, especially the left one. The *ramus interventricularis paraconalis* had a higher incidence of myocardial bridges, which occurred in the middle third of the vessel. When observed in the subsinuous branch, they had thinner characteristics in width and thickness.

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Author’s Contributions

VLB, KFL, AMAR and JVM participated in its design, dissected the hearts, made the measurements, collected the animal data, tabulated the data and measures for statistical analysis, JMBO participated in the design of the study and performed the statistical analysis, AMSB participated in the collections and applied the specimen conservation techniques, EPM participated in the design of the study, in the writing and in the final revision of the manuscript, DO conceived of the study, and participated in its design, analysis and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

Competing Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

BOMBONATO, P. P.; DOMINGOS, C. de O; MARIANA, A. N. B; SILVA, F. O. C.; INTELIZANO, W. Ocorrência de pontes do miocárdio em suínos. **Brazilian Journal of Veterinary Research and Animal Science**, v. 31, n. 2, p. 107-111, 1994. https://pesquisa.bvsalud.org/portal/resource/pt/lil-240148

BORELLI, V.; FERNANDES FILHO, A. Sobre a origem do *ramus descendens subsinuosus* em bovinos. **Revista da Faculdade de Medicina Veterinária**, São Paulo, v. 8, n. 2, p. 367-373, 1970. http://docplayer.com.br/110147723-Sobre-a-origem-do-r-a-m-u-s-d-e-s-c-e-n-d-e-n-s-subsinuosus.html

BRODSKY, S. V.; ROH, L.; ASHAR, K.; BRAUN, A.; RAMASWAMY, G. Myocardial bridging of coronary arteries: a risk factor for myocardial fibrosis? **International Journal of Cardiology**, v. 124, n. 3, p. 391-392, 2008. https://pubmed.ncbi.nlm.nih.gov/17399815/

CORREIA-OLIVEIRA, M.; MORAES, S. O. S.; GOMES, M. S.; PALHANO, H. B.; ABIDU-FIGUEIREDO, M. Dominância entre as artérias coronárias em bovinos mestiços. **Revista Brasileira de Ciência Veterinária**, v. 21, n. 2, p. 82-85, 2014. http://doi.editoracubo.com.br/10.4322/rbcv.2014.027

CORREIA-OLIVEIRA, M.; HERNANDEZ, J. M. F.; ABIDU-FIGUEIREDO, M. Morfometria cardíaca e distribuição das artérias coronárias em bovinos mestiços. **Biotemas**, v. 26, n. 2, p. 199-207, 2013. https://periodicos.ufsc.br/index.php/biotemas/article/view/2175-7925.2013v26n2p199

DYCE, K. M.; SACK, W. O.; WENSING, C. J. G. **Tratado de Anatomia Veterinária**. 4ª ed. Rio de Janeiro: Elsevier, 2010.

FRANDSON, R. D.; WILKE, W. L.; FAILS, A. D. **Anatomia e Fisiologia do Animais de Fazenda**. 7ª ed. Rio de Janeiro: Guanabara Koogan, 2017.

GETTY, R. **Sisson/Grossman Anatomia dos Animais Domésticos**. Rio de Janeiro: Guanabara Koogan, 1986.

GULMEZ, N.; SAH, H. The relationships between the myocardial bridge and ramus interventricularis paraconalis characteristics in lamb and sheep. **Anatomia, Histologia, Embryologia**, v. 50, n. 2, p. 260-265, 2021. https://pubmed.ncbi.nlm.nih.gov/33009861/

INTERNATIONAL COMMITTEE ON VETERINARY GROSS ANATOMICAL NOMENCLATURE. **Nomina Anatomica Veterinaria**. 6ª ed. World Association of Veterinary Anatomists: editorial Committee: Rio de Janeiro, 2017.

ISHIKAWA, Y.; KAWAWA, Y.; KOHDA, E.; SHIMADA, K.; ISHII, T. Significance of the anatomical properties of a myocardial bridge in coronary heart disease. **Circulation Journal**, v. 75, n. 7, p. 1559-1566, 2011. https://pubmed.ncbi.nlm.nih.gov/21467656/

KÖNIG, H. E.; LIEBICH, H. E. **Anatomia dos Animais Domésticos**. 4ª ed. Porto Alegre: Artmed, 2011.

MARTINS, A-K.; SEVERINO, R. S.; CARDOSO, J. R.; FIDELIS, A. A.; RODRIGUES, T. V. Vascularização arterial do nó atrioventricular e tronco do fascículo atrioventricular em bovinos da raça Nelore. **Bioscience Journal**, v. 24, n. 3, p. 102-107, 2008. http://www.seer.ufu.br/index.php/biosciencejournal/article/view/6754

NASR, A. Y. Myocardial bridge and coronary arteries: morphological study and clinical significance. **Folia Morphologica (Warsz)**, v. 73, n. 2, p. 169-182, 2014. https://pubmed.ncbi.nlm.nih.gov/24902096/

NIKOLIĆ, V.; BLAGOJEVI, Z.; STIJAK, L.; RADONJI, V.; DORDEVI, M.; KOVACEVI, D.; FILIPOVI, B. Myocardial bridges over the ramus interventricularis anterior and its branches in *Cercopithecus aethiops sabeus*. **Acta Veterinaria**, v. 59, n. 2-3, p. 213-221, 2009. http://www.doiserbia.nb.rs/img/doi/0567-8315/2009/0567-83150903213N.pdf

OECD/FAO. **OECD/FAO Agricultural Outlook 2020-2029**. OECD: Paris: FAO: Rome; 2020. http://www.fao.org/publications/oecd-fao-agricultural-outlook/2020-2029/en/

RIBEIRO, A. L. C.; SEVERINO, R. S.; GUERRA, R. R.; FAVARON, P. O.; TOMMASI JUNIOR, H. L. P.; RICCI, R. E. G.; FRANCIOLLI, P. R. F.; BOMBONATO, P. P. Biometria de pontes de miocárdio em muares (*Equus caballus* x *Equus asinus* – Linnaeus 1758). **Biotemas**, v. 22, n. 3, p. 177-184, 2009. https://periodicos.ufsc.br/index.php/biotemas/article/view/2175-7925.2009v22n3p177/0

RODRIGUES, T. M. A.; PALMEIRA, J. A. O.; MENDONÇA, J. T. DE; GOMES, O. M. Estudo evolutivo da anatomia das artérias coronárias em espécies de vertebrados com técnica de moldagem em acetato de vinil (vinilite). **Revista Brasileira de Cirurgia Cardiovascular**, v. 14, n. 4, p. 331-339, 1999. https://www.rbccv.org.br/article/781/pt-BR/estudo-evolutivo-da-anatomia-das-arterias-coronarias-em-especies-de-vertebrados-com-tecnica-de-moldagem-em-acetato-de-vinil--vinilite-

SAMPAIO, I. B. M. **Estatística Aplicada à Experimentação Animal**. 4ª ed. Belo Horizonte: Fundação de Ensino e Pesquisa em Medicina Veterinária e Zootecnia, 2015.

SANTOS, J. C. C.; BARRETO, J. E. F.; RODRIGUES, C. F. de S.; LIMA JÚNIOR, F. A. S. de; OLIVEIRA, A. de S. BRAGA. Morphological analysis of myocardial bridges and coronary arterial dominance in northeast Brazil. **Morphologie**, 2021. https://pubmed.ncbi.nlm.nih.gov/33775545/

SANTOS, J. W.; BOMBONATO, P. P.; BELETTI, M. E.; SEVERINO, R. S.; CARNEIRO E SILVA, F. O. Pontes de miocárdio em bovinos da raça Canchim, I - Aspectos microscópicos. **Brazilian Journal of Veterinary Research and Animal Science**, v. 37, n. 2, p. 128-131, 2000. https://www.scielo.br/j/bjvras/a/cNWz5Ctd93NXdvKCJg8Rqmv/?lang=pt

SANTOS, J. W.; WAFAE, N.; BELETTI, M. E. Ponte miocárdica associada a lesões cardiovasculares em bovinos adultos da raça Canchim. **Arquivos Brasileiros de Cardiologia**, v. 98, n. 1, p. 22-28, 2011. https://www.scielo.br/j/abc/a/YPJJwyvTBxKvmcjM54m3PSn/abstract/?lang=pt

SEVERINO, R. S.; CARNEIRO E SILVA, F. O; SANTOS, A. L. Q; DRUMMOND, S. S; BOMBONATO, P. P; DURAN, F. P; MARÇAL, A. V. Pontes de miocárdio em bovinos azebuados. **Brazilian Journal of Veterinary Research and Animal Science**, v. 34, n. 5, p. 288-291, 1997. https://pesquisa.bvsalud.org/portal/resource/pt/lil-257117

SEVERINO, R. S.; BOMBONATO, P. P. Ocorrência de pontes de miocárdio em bovinos das raças Gir, Guzerá, Indubrasil e Nelore. **Brazilian Journal of Veterinary Research and Animal Science**, v. 29, n. 1, p. 15-30, 1992. https://www.bvs-vet.org.br/vetindex/periodicos/brazilian-journal-veterinary-research-and-animal-s/29-(1992)-1/ocorrencia-de-pontes-de-miocardio-em-bovinos-das-racas-gir-guzera-indu/

SHINJO, S. K.; OBA-SHINJO, S. M.; PRATES, N. E. V. B. Bovine myocardial bridge morphology and association with coronary atherosclerosis, **Brazilian Journal oh Morphological Sciences**, v. 21, n. 2, p. 95-98, 2004. https://pesquisa.bvsalud.org/portal/resource/pt/lil-406361

SIERVULI, M. T. F.; SILVA, A. de S.; SILVA, A. C. da; MUZZI, R. A. L.; SANTOS, G. A. B. Infarto do miocárdio: alterações morfológicas e breve abordagem da influência do exercício físico. **Revista Brasileira de Cardiologia**, v. 27, n. 5, p. 349-355, 2014. http://www.onlineijcs.org/english/sumario/27/pdf/v27n5a09.pdf

TARANTINI, G.; MIGLIORE, F.; CADEMARTIRI, F.; FRACCARO, C.; ILICETO, S. Left anterior descending artery myocardial bridging: a clinical approach. **Journal of the American College of Cardiology**, v. 68, n. 25, p. 2887-2899, 2016. https://pubmed.ncbi.nlm.nih.gov/28007148/

TERAGAWA, H.; FUKUDA, Y.; MATSUDA, K.; HIRAO, H.; HIGASHI, Y.; YAMAGATA, T.; OSHIMA, T.; MATSUURA, H.; CHAYAMA, K. Myocardial bridging increases the risk of coronary spasm. **Clinical Cardiology**, v. 26, n. 8, p. 377-83, 2003. https://pubmed.ncbi.nlm.nih.gov/12918640/

ZHAO, D. H.; FAN, Q.; NING, J. X.; WANG, X.; TIAN, J. Y. Myocardial bridge-related coronary heart disease: Independent influencing factors and their predicting value. **World Journal of Clinical Cases**, v. 7, n. 15, p. 1986-1995, 2019. https://europepmc.org/article/MED/31423430

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