BJIHS
ISSN 2674-8169
Qualis B3 CAPES 2021-2024 | Latindex | DOI | Google Acadêmico

# *MORPHOMETRIC ANALYSIS OF HUMAN CORONARY ARTERIES: ANATOMICAL VARIABILITY, DIMENSIONAL CORRELATIONS, AND CLINICAL IMPLICATIONS*

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https://doi.org/10.36557/2674-8169.2026v8n7p1052-1070
Artigo recebido em 27 de Junho e publicado em 27 de Julho de 2026

*ARTIGO ORIGINAL*

**RESUMO**

**Introdução:** As artérias coronárias apresentam variações morfométricas que podem influenciar a interpretação de exames de imagem e o planejamento de procedimentos diagnósticos, intervencionistas e cirúrgicos. Entretanto, os valores descritos na literatura mostram considerável variabilidade entre diferentes populações e metodologias. **Objetivo:** Analisar o comprimento e o diâmetro das artérias coronárias direita e esquerda em corações humanos provenientes de cadáveres formalizados. **Material e métodos:** Estudo anatômico observacional, descritivo e transversal realizado em 30 corações masculinos de cadáveres adultos fixados em formaldeído a 10%. As artérias coronárias foram dissecadas e submetidas à mensuração do comprimento e do diâmetro com paquímetro digital. Os dados foram analisados por estatística descritiva, teste de Shapiro-Wilk e correlação de Spearman, adotando-se significância de 5%. **Resultados:** A artéria coronária direita apresentou comprimento médio de 5,45 ± 0,92 cm e diâmetro de 0,203 ± 0,132 cm, enquanto o tronco da artéria coronária esquerda apresentou comprimento de 1,13 ± 0,44 cm e diâmetro de 0,250 ± 0,133 cm. Observou-se correlação positiva moderada entre os comprimentos das artérias coronárias direita e esquerda ($\rho = 0,457$; $p = 0,011$) e correlação negativa moderada entre o comprimento e o diâmetro da artéria coronária esquerda ($\rho = -0,509$; $p = 0,004$). **Conclusão:** As artérias coronárias apresentaram expressiva variabilidade morfométrica, com associações significativas entre algumas de suas dimensões. Esses achados ampliam o conhecimento sobre a anatomia coronariana e fornecem subsídios para a interpretação

de exames de imagem e o planejamento de intervenções cardiovasculares.

**Palavras-chave:** Vasos coronários; Variação anatômica; Morfometria; Artéria coronária direita; Tronco da artéria coronária esquerda.

# MORPHOMETRIC ANALYSIS OF HUMAN CORONARY ARTERIES: ANATOMICAL VARIABILITY, DIMENSIONAL CORRELATIONS, AND CLINICAL IMPLICATIONS

**ABSTRACT**

**Introduction:** Coronary arteries exhibit morphometric variations that may influence the interpretation of cardiovascular imaging and the planning of diagnostic, interventional, and surgical procedures. However, morphometric values described in the literature show considerable variability across different populations and methodologies employed. **Objective:** To analyze the morphometric characteristics of the right coronary artery and the left main coronary artery in human hearts obtained from formalin-fixed cadavers. **Material and methods:** An observational, descriptive, cross-sectional anatomical study conducted on 30 hearts from adult male cadavers fixed in 10% formalin. The coronary arteries were dissected, and their length and diameter were measured using a digital caliper. Data were analyzed using descriptive statistics, the Shapiro–Wilk test, and Spearman's correlation coefficient, with statistical significance set at $p < 0.05$. **Results:** The right coronary artery had a mean length of 5.45 ± 0.92 cm and a mean diameter of 0.203 ± 0.132 cm, whereas the left main coronary artery had a mean length of 1.13 ± 0.44 cm and a mean diameter of 0.250 ± 0.133 cm. A moderate positive correlation was found between the lengths of the right and left coronary arteries ($\rho = 0.457$; $p = 0.011$), and a moderate negative correlation was observed between the length and diameter of the left main coronary artery ($\rho = -0.509$; $p = 0.004$). **Conclusion:** Coronary arteries exhibited marked morphometric variability, with significant associations among selected morphometric parameters. These findings broaden the understanding of coronary anatomy and provide support for the interpretation of imaging examinations and the planning of cardiovascular interventions.

**Keywords:** Coronary vessels; Anatomic variation; Morphometry; Right Coronary Artery; Left Main Coronary Artery.

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## Introduction

The coronary arteries, which supply blood to the myocardium, exhibit anatomical variations in their origin, course, branching pattern, and vascular dimensions. Knowledge of these anatomical characteristics is essential for the accurate interpretation of cardiovascular imaging, particularly coronary computed tomography angiography, as well as for planning diagnostic, interventional, and surgical procedures (Andrade, 2006). Anatomical studies have demonstrated that coronary artery length and diameter vary among individuals and populations. Kumar et al. (2018), Kanté et al. (2026), and Priya et al. (2023) observed significant morphometric differences in the left main coronary artery and its main branches, while Ballesteros et al. (2013) reported wide variability in the caliber and length of the right coronary artery. Likewise, Ilayperuma et al. (2011) also identified differences in coronary artery diameter between men and women, indicating that biological factors may influence their dimensions.

Furthermore, the length of the left main coronary artery appears to be associated to its branching pattern, as demonstrated by Pereira da Costa Sobrinho et al. (2019). These anatomical variations are clinically relevant because vessels with smaller diameters or distinct courses and lengths may influence angiographic assessment, endovascular device selection, and myocardial revascularization procedures. In addition, recent advances in quantitative coronary angiography, together with artificial intelligence-assisted image analysis, have further emphasized the need for reliable anatomical parameters to improve image interpretation and optimize therapeutic planning for coronary artery disease (Gurav et al., 2024).

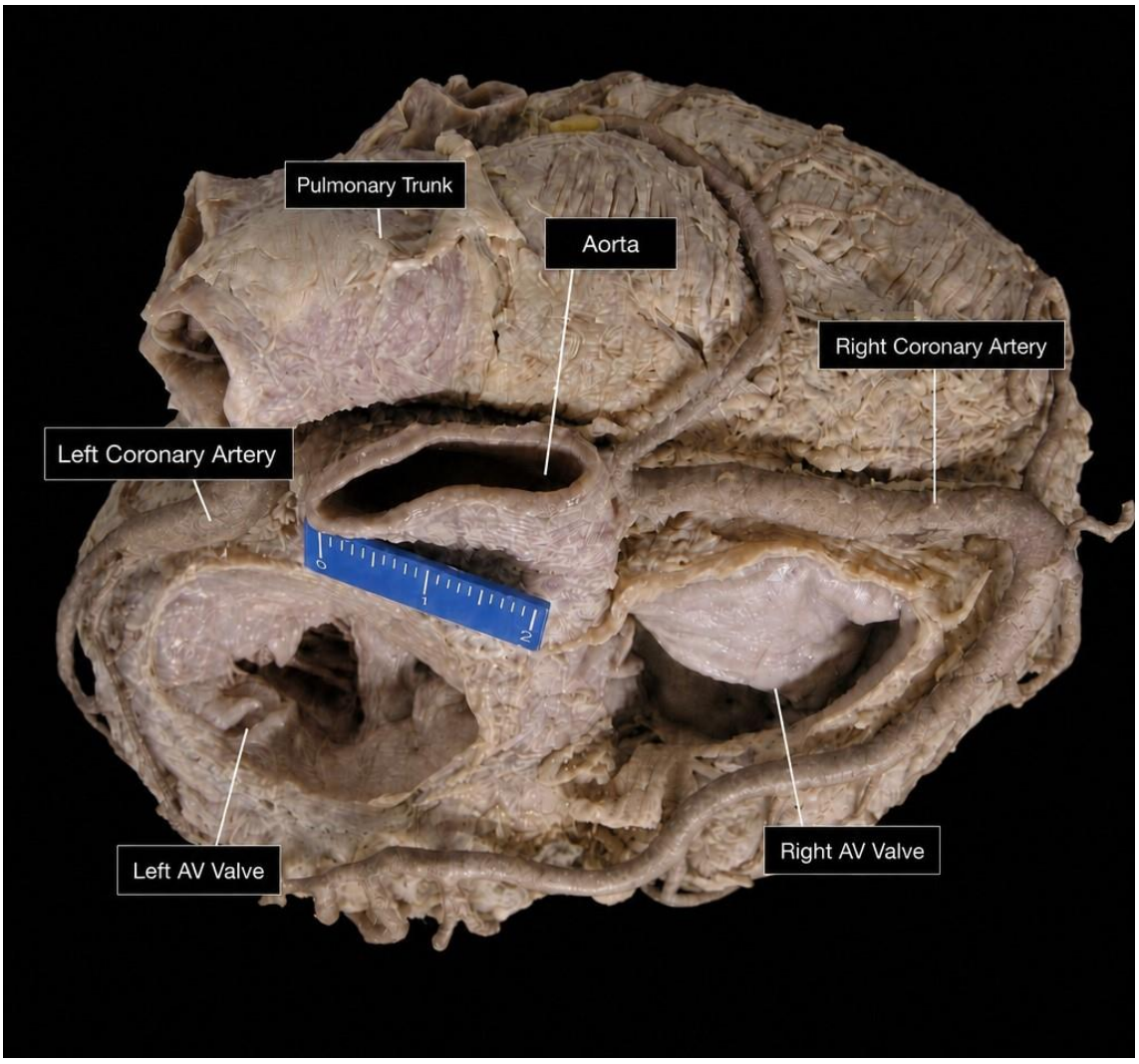
Although several studies have investigated coronary morphometry, the reported measurements remain heterogeneous, possibly due to population differences, measurement methods, and specimen preservation conditions. Therefore, anatomical studies using cadaveric specimens remain essential for establishing reliable morphometric reference values. Accordingly, the present study aimed to analyze the length and diameter of the right coronary artery and the left main coronary artery in human hearts obtained from formalin-fixed cadavers.

## Material and Methods

An observational, descriptive, cross-sectional anatomical study was conducted on 30 hearts obtained from adult male cadavers fixed in 10% formalin solution. The specimens were provided by the Human Anatomy Laboratory of the Federal University of Sergipe (UFS), in accordance with Brazilian Law Nº. 8,501 of November 30, 1992, which regulates the use of unclaimed bodies for teaching and research purposes.

Only hearts without pathological alterations, congenital malformations, evidence of trauma, or signs of previous surgical procedures that could affect coronary artery anatomy on macroscopic examination were included. After careful removal of the epicardial adipose tissue, the right coronary artery and the left main coronary arteries were dissected to allow complete exposure for morphometric analysis (**Figure** 1).

**Figure** 1. Superior view of the base of the heart showing the coronary arteries and cardiac valves.



**Legend:**

**AV** → Atrioventricular (Right AV valve or tricuspid / Left AV valve or mitral)

In the right coronary artery, length was defined as the distance between the coronary ostium in the ascending aorta and the origin of the first right ventricular branch. In the left main coronary artery, length was defined as the distance between the coronary ostium and its bifurcation or trifurcation. The external diameter of both arteries was measured at the midpoint of the segment used for length determination. All morphometric measurements were obtained using a digital caliper with a resolution of 0.01 mm. Each measurement was performed twice by the same investigator at different time points, and the arithmetic mean of the two measurements was used for statistical analysis to minimize measurement error and enhance the reproducibility of the results.

**Statistical Analysis**

Descriptive statistics were initially calculated to characterize the sample, including the mean, standard deviation, median, minimum, and maximum values. The distribution of the variables was assessed using the Shapiro-Wilk test (Royston, 1983). As most variables did not follow a normal distribution, nonparametric tests were used for the inferential analyses. The association between quantitative variables was analyzed using Spearman's correlation coefficient (ρ), which is appropriate for non-normally distributed data (Alsaqr, 2021). The magnitude of the correlation was interpreted according to the following criteria: weak ($\rho < 0.40$), moderate ($0.40 \leq \rho < 0.70$), and strong ($\rho \geq 0.70$). All statistical analyses were performed using jamovi software (version 2.6; The jamovi Project, Sydney, Australia), with a significance level set at 5% ($p < 0.05$).

## RESULTS

The study included a sample of 30 adult male cadavers, with a mean age of 38.2±9.76 years and a median of 37.5 years, and an age range of 24–54 year. The right coronary artery had a mean length of 5.45±0.92 cm and a median lenght of 5.78 cm (range: 4.00–6.65 cm). The left main coronary artery had a mean length of 1.13±0.44 cm and a median length of 1.24 cm (range: 0.40–2.00 cm). Regarding arterial diameter, the right coronary artery had a mean diameter of 0.203± 0.132 cm and a median diameter

of 0.200 cm (range: 0.10–0.80 cm), whereas the left main coronary artery had a mean diameter of 0.250±0.133 cm and a median of 0.200 cm (range: 0.12–0.60 cm) (**Table** 1).

**Table** 1. Descriptive statistics of the study sample and morphometric measurements of coronary artery length and diameter.

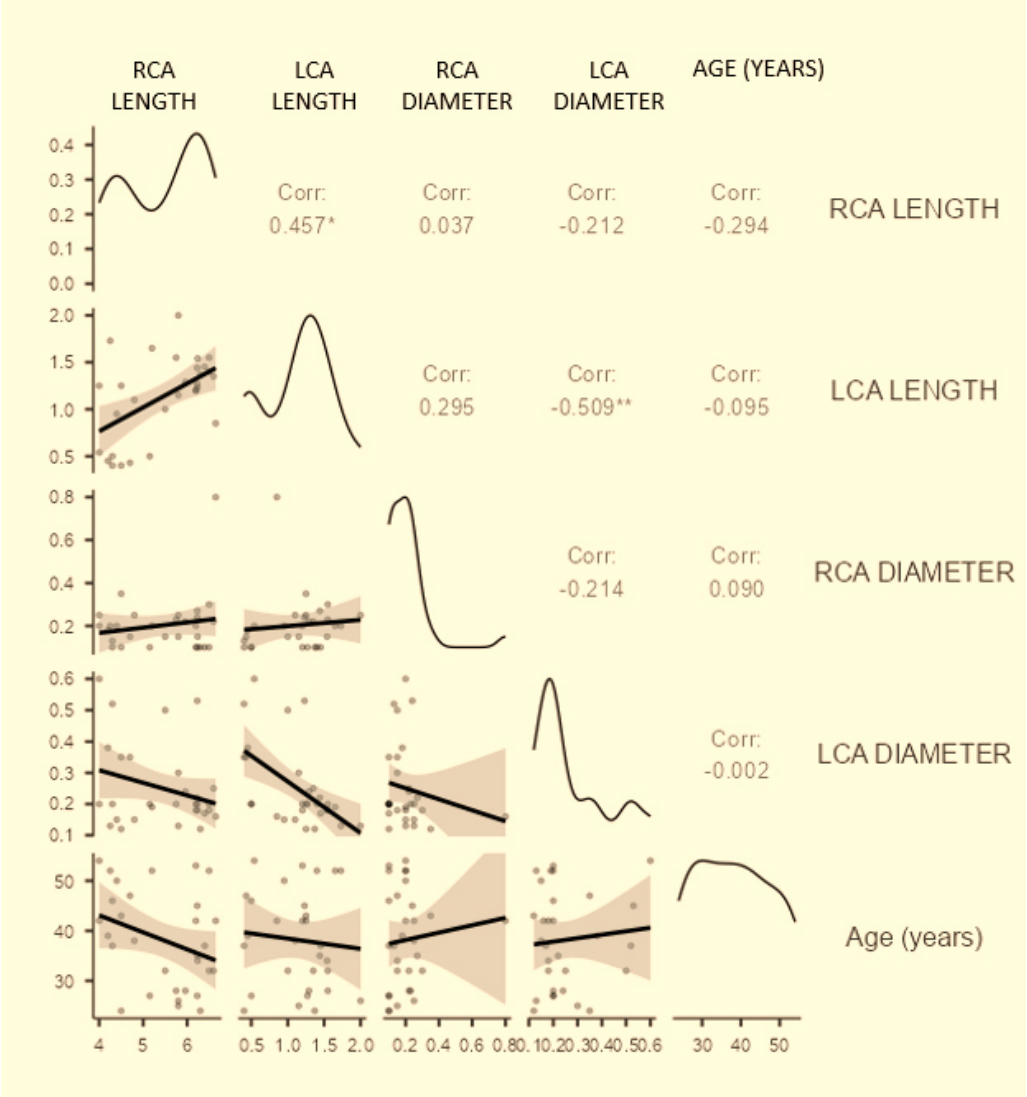
| | Age (years) | RCA length | LCA length | RCA diameter | LCA diameter |
|---|---|---|---|---|---|
| **n** | 30 | 30 | 30 | 30 | 30 |
| **Mean** | 38.2 | 5.45 | 1.13 | 0.203 | 0.250 |
| **Median** | 37.5 | 5.78 | 1.24 | 0.200 | 0.200 |
| **Standard deviation** | 9.76 | 0.922 | 0.442 | 0.132 | 0.133 |
| **Minimum** | 24 | 4.00 | 0.400 | 0.100 | 0.120 |
| **Maximum** | 54 | 6.65 | 2.00 | 0.800 | 0.600 |
| **Shapiro-Wilk W** | 0.934 | 0.878 | 0.925 | 0.650 | 0.794 |
| **Shapiro-Wilk p-value** | 0.064 | 0.003 | 0.036 | <.001 | <.001 |

**Legend:**

**RCA** = Right coronary artery; **LMCA** = Left main coronary artery.

The Shapiro–Wilk test indicated that age was normally distributed ($p = 0.064$), whereas the remaining variables showed non-normal distribution ($p < 0.05$). A moderate positive correlation was observed between the lengths of the right coronary artery and the left main coronary artery ($\rho = 0.457$; $p = 0.011$). In addition, a moderate negative correlation was found between the length and diameter of the left main coronary artery ($\rho = -0.509$; $p = 0.004$). No significant correlations were found between age and the other analyzed variables ($p > 0.05$) or between the diameter and length of the right coronary artery ($p > 0.05$) (**Figure** 2).

**Figure** 2. Correlation of age and coronary artery morphometric measurements.




**RCA =** Right coronary artery; **LCA =** Left main coronary artery.

## Discussion

The present study demonstrated wide morphometric variability of the coronary arteries in formalin-fixed human hearts, as evidenced by the differences observed in the length and diameter of the analyzed segments. The right coronary artery had a mean length of 5.45 ± 0.92 cm and a mean diameter of 0.203 ± 0.132 cm, whereas the left main coronary artery had a mean length of 1.13 ± 0.44 cm and a mean diameter of 0.250 ± 0.133 cm. In addition to these morphometric differences, a moderate positive correlation was identified between the lengths of the right coronary artery and left main

coronary artery, and a moderate negative correlation was found between the length and diameter of the left main coronary artery. Taken together, these findings reinforce that coronary anatomy exhibits marked individual variability, an aspect that should be considered both in anatomical interpretation and in the planning of diagnostic, interventional, and surgical procedures.

The mean length of the left main coronary artery observed in the present study (1.13 ± 0.44 cm) was greater than that reported by Pereira da Costa Sobrinho et al. (2019) (0.853 ± 0.403 cm), similar to the value found by Kumar et al. (2018) (1.02 ± 0.35 cm), and lower than that reported by Kanté et al. (2026) (1.50 ± 0.10 cm). Despite these differences, all of these studies converge in demonstrating that the left main coronary artery exhibits wide morphometric variability, likely related to population differences, the anatomical criteria used to define the segment, and the distinct measurement methods employed. This variability was further supported by Priya et al. (2023), who reported that most left main coronary artery lengths ranged from 0.50 to 1.50 cm, an interval that also includes both the mean and median values observed in the present study.

The differences observed among studies become more understandable when the anatomical characteristics of the left main coronary artery are considered. Pereira da Costa Sobrinho et al. (2019) demonstrated that the length of the left main coronary artery increases progressively with the complexity of its branching pattern, with mean values of 0.644 cm in bifurcations, 0.977 cm in trifurcations, and 1.078 cm in tetrafurcations. Although the present study did not stratify the results according to branching pattern, the observed length range, (0.40 to 2.00 cm) suggests that different anatomical configurations were likely represented in the sample. Therefore, the observed variability should not be interpreted solely as reflecting population differences but also as an inherent feature of coronary arterial anatomy.

This variability has important clinical implications. Shorter left main coronary arteries reduce the distance between the left coronary artery ostium and the terminal division, increasing the likelihood that proximal atherosclerotic lesions may simultaneously involve the left anterior descending artery and the circumflex artery. Conversely, longer left main trunks provide a longer landing zone for the advancement

of catheters, balloons, and stents, although lesions located close to the bifurcation or trifurcation may require more complex interventional techniques. In this context, the findings of Priya et al. (2023) reinforce that preoperative characterization of left main coronary artery length constitutes an important step in the planning of angioplasties and myocardial revascularization surgery.

The mean diameter of the left main coronary artery found in the present study (0.250 ± 0.133 cm) was lower than those reported by Kumar et al. (2018) and Kanté et al. (2026) (0.434 ± 0.201 cm). However, this difference should be interpreted with caution. In the present study the arterial diameter was measured at the midpoint of the segment between the ostium and the bifurcation or trifurcation, whereas the comparative studies performed measurements from more proximal portions of the vessels, close to its origin, where the caliber is naturally greater. Furthermore, the use of formalin-fixed hearts may result in tissue shrinkage and vascular collapse, factors that may contribute to the reduction of the external dimensions observed during anatomical dissection.

Although methodological differences partially explain this divergence, the wide range of values obtained indicates that the caliber of the left main coronary artery also exhibits important individual variability. This characteristic has direct application in interventional cardiology, as inadequate sizing of balloons and stents may predispose to arterial dissection, insufficient expansion, device malapposition, restenosis, and thrombosis. Thus, rather than establishing a universal reference value, these findings reinforce the need for individualized measurement using imaging methods prior to therapeutic procedures.

One of the most relevant findings of the present study was the identification of a moderate negative correlation between the length and diameter of the left main coronary artery, indicating that longer segments tended to have a smaller caliber at the midpoint. The studies by Pereira da Costa Sobrinho et al. (2019), Kumar et al. (2018), Priya et al. (2023), and Kanté et al. (2026) described the length, diameter, and branching patterns independently, without investigating the statistical relationship between these variables. Thus, although direct comparison with the literature is not possible, the present findings expands the current understanding of the left main coronary artery and

suggests that its length and caliber are not entirely independent anatomical characteristics.

From an anatomical standpoint, a possible explanation for this association would be the progressive tapering of longer trunks before the terminal division. However, this hypothesis remains speculative, as the diameter was measured at a single point along the segment. Furthermore, factors such as branching pattern, coronary dominance, cardiac mass, and the myocardial territory supplied may also simultaneously influence these two variables. Future studies that perform serial measurements along the vessel and combine anatomical data with imaging methods may clarify the mechanisms underlying this morphometric relationship.

The clinical implications of this finding deserve emphasis. Longer left main coronary trunks associated with a smaller caliber may increase the complexity of percutaneous coronary intervention, requiring greater precision in the selection of device sizing and catheter manipulation. When this anatomical configuration is associated with trifurcation or the presence of an intermediate branch, simultaneous protection of the arterial branches becomes even more challenging, increasing the technical complexity of angioplasty and myocardial revascularization surgery.

Regarding the right coronary artery, the present study found a mean length of 5.45 ± 0.92 cm and a mean diameter of 0.203 ± 0.132 cm, likewise demonstrating wide morphometric variability. Although few studies have systematically described the length of this vessel, the work of Ballesteros et al. (2013) and Ilayperuma et al. (2011) reported considerable variability in the arterial diameter and branching patterns of the right coronary artery, corroborating the marked anatomical variability observed in this investigation. The mean diameter found was lower than that reported by Ballesteros et al. (2013), who described 0.342 ± 0.066 cm in the proximal segment and 0.290 ± 0.050 cm at the level of the acute margin of the heart, as well as the values of Ilayperuma et al. (2011), who found 0.599 ± 0.123 cm at the origin of the right coronary artery and 0.528 ± 0.145 cm at 2.5 cm distal to its origin. These differences likely reflect the distinct anatomical points used for measurement, since arterial caliber progressively decreases along its course, as well as to differences in specimen preparation method, particularly tissue shrinkage resulting from formalin fixation.

The findings of Ballesteros et al. (2013) demonstrated that the anatomical variability of the right coronary artery is not restricted to its caliber, but also encompasses the origin and distribution of the branches destined for the right ventricle, the atria, and, most notably, the cardiac conduction system. This observation complements the findings of the present study by indicating that dimensional differences should be interpreted in the context of the overall coronary arterial architecture. Thus, vessels with similar lengths and diameters may have distinct functional relevance depending on the supplied territory and the origin of the nodal branches, an aspect of great importance during myocardial revascularization procedures, valve surgeries, and interventions involving the aortic root.

The absence of a significant correlation between the length and diameter of the right coronary artery suggests that these morphometric parameters are influenced by distinct anatomical factors. Unlike the left main coronary artery, the right coronary artery follows a long epicardial course, giving rise to multiple atrial and ventricular branches until reaching the crux of the heart. Furthermore, its anatomical development is closely associated to the pattern of coronary dominance. Sakamoto et al. (2013) demonstrated that dominance significantly influences coronary flow distribution, with greater participation of the right coronary artery in right dominance and greater contribution of the circumflex artery in balanced and left dominance patterns. Although coronary dominance was not analyzed in the present study, these results suggest that differences in the supplied territory may influence arterial caliber independently of vessel length.

Another relevant finding of the presente study was the identification of a moderate positive correlation between the lengths of the right coronary artery and the left main coronary artery, indicating that individuals with a longer segment in one artery also tended to have a longer segment in the other. The studies by Pereira da Costa Sobrinho et al. (2019), Kumar et al. (2018), Priya et al. (2023), Kanté et al. (2026), Ballesteros et al. (2013), and Ilayperuma et al. (2011) focused on describing coronary artery dimensions individually, without investigating the relationship between these measurements. Therefore, the present findings provide a novel perspective to coronary morphometry by suggesting that part of the observed dimensional variability may occur in a coordinated manner between both arterial systems. However, this interpretation

should be approached with caution, as distinct anatomical segments were analyzed. In the right coronary artery, measurements were obtained from the segment extending between the coronary ostium and the origin of the first right ventricular branch, whereas in the left coronary artery, measurements were obtained between the coronary ostium and its terminal division. Therefore, the observed correlation should not be interpreted as reflecting proportionality between the total lengths of the coronary arteries, but rather as an association between the segments defined by the measurement protocol.

From a functional standpoint, this proportionality may be related to overall heart size, aortic root morphology, the positioning of the coronary ostia, and the arterial branching pattern. However, because these variables were not assessed in the present study, no causal relationship can be established. Future studies should integrate anthropometric data, cardiac mass, coronary dominance, and arterial division patterns to clarify the factors responsible for this association.

The absence of a significant correlation between age and the morphometric variables indicates that, within the age range evaluated, aging did not exert a detectable influence on coronary artery length or diameter. This finding should be interpreted in the context of the sample, which was composed exclusively of adult hearts without relevant macroscopic alterations. Coma-Canella et al. (1999) demonstrated that cardiovascular remodeling processes may modify coronary morphology under specific clinical conditions, indicating that arterial dimensions do not remain constant throughout life or in the presence of cardiovascular disease. Thus, the results presented herein should not be extrapolated to elderly populations or individuals with cardiovascular disease.

Another relevant aspect concerns the influence of sex on coronary morphometry. Ilayperuma et al. (2011) observed significantly larger coronary artery diameters in men than in women. The exclusive use of male hearts reduced the heterogeneity resulting from sexual dimorphism and increased the internal consistency of the sample. However, this characteristic limits the extrapolation of the findings to the female population and highlights the need for specific studies involving both sexes.

The differences observed among various studies also reflect important

methodological heterogeneity. Vidhale et al. (2024) highlighted that population variations, anatomical criteria, dissection methods, measurement instruments, specimen preservation status, and the definition of reference points directly influence the morphometric values obtained. Furthermore, anatomical studies predominantly measure the external diameter of coronary arteries, whereas angiographic and tomographic examinations assess the vascular lumen under physiological conditions. Thus, morphometric data obtained from cadaveric specimens and living individuals should be considered complementary, rather than directly equivalent.

In this context, Dundas et al. (2023) emphasized the importance of integrating traditional anatomical studies with contemporary imaging methods, such as computed tomography angiography and three-dimensional reconstructions. Whereas anatomical dissection provides detailed information on vascular morphology and anatomical relationships, imaging techniques allow the assessment of vascular morphology under physiological conditions, thereby expanding the clinical applicability of morphometric studies and facilitating the planning of diagnostic, interventional, and Surgical cardiovascular procedures.

From a surgical standpoint, Pradenas et al. (2009) demonstrated that minor anatomical variations may have a major impact during cardiac valve procedures. The authors reported that the distance between the circumflex artery and the left atrioventricular annulus can be as small as 0.38 cm in formalin-fixed hearts and 0.30 cm in fresh hearts, especially in left-dominant coronary circulation, thereby increasing the risk of arterial injury during annuloplasty and valve replacement. Although the present study did not analyze topographic relationships, the observed variability in length and diameter reinforces the need for individualized anatomical planning prior to cardiovascular interventions, particularly when performed in close proximity to the coronary sulci.

Several limitations should be considered when interpreting the findings of the present study . The relatively small number of specimens, the exclusive inclusion of male hearts, the use of formalin-fixed specimens, and the lack of information on coronary dominance, cardiac weight, body surface area, and branching coronary patterns restrict the generalizability of the findings. Furthermore, arterial diameter was measured at only

one point of each arterial segment, precluding the assessment of progressive tapering along the vessel.

Despite these limitations, the presente study has several important strengths. The standardization of the dissection protocol, the performance of all measurements by a single investigator, the repetition of measurements at different time points, and the application of statistical methods appropriate for the data distribution confer high methodological consistency to the results. Furthermore, the simultaneous analysis of coronary artery length, diameter, and the correlations between these variables expands the current understanding of coronary artery morphometric organization, an aspect still underexplored in the literature.

In summary, the presente findings confirm that the coronary arteries exhibit substantial morphometric variability, in agreement with the findings of Pereira da Costa Sobrinho et al. (2019), Kumar et al. (2018), Priya et al. (2023), Kanté et al. (2026), Ballesteros et al. (2013), and Ilayperuma et al. (2011). Moreover, the identification of a positive correlation between the lengths of the right and left coronary arteries, together with a negative correlation between the length and diameter of the left main coronary artery represents an original contribution of this study, broadening the knowledge on the morphometric organization of the coronary circulation. These findings reinforce the importance of individualized anatomical assessment for the interpretation of imaging exams, the planning of angioplasties, myocardial revascularization surgery, valve procedures, and other cardiovascular interventions, contributing to greater diagnostic and therapeutic safety.

## Conclusion

The present study demonstrated that the coronary arteries exhibit significant morphometric variability in formalin-fixed human hearts. The right coronary artery had a mean length of 5.45 ± 0.92 cm and a mean diameter of 0.203 ± 0.132 cm, whereas the left main coronary artery had a mean length of 1.13 ± 0.44 cm and a mean diameter of 0.250 ± 0.133 cm. Furthermore, a moderate positive correlation was identified between the lengths of the right coronary artery and the left main coronary artery and a moderate negative correlation between the length and diameter of the left main coronary artery, indicating that these morphometric characteristics do not vary

independently. These findings further support the substantial anatomical variability of the coronary circulation and provide new insights on the morphometric organization, supporting the interpretation of cardiovascular imaging interpretation and for the planning of interventional and surgical procedures, such as angioplasties, myocardial revascularization surgery, and valve interventions. Future studies involving larger and more diverse populations, including both sexes and different patterns of coronary dominance, together with the integration of anatomical methods with advanced imaging techniques, may further improve the understanding of coronary arteries morphological variability and its clinical implications.

## Funding

This research did not receive any specific funding from funding agencies in the public, commercial, or not-for-profit sectors.

## Conflict of interests

The authors declare no conflict of interests.

## Acknowledgments

**In Memoriam of Dr. Marcos Vinicius da Silva**

The authors dedicate this work to the memory of Dr. Marcos Vinicius da Silva, whose scientific dedication, intellectual curiosity, and commitment to anatomical research left a lasting legacy despite his untimely passing. Professor José Aderval Aragão had the privilege of mentoring Dr. Marcos Vinicius da Silva during his undergraduate research initiation, witnessing the development of an outstanding young researcher who later became a respected colleague and educator. His enthusiasm for science, unwavering work ethic, and pursuit of academic excellence continue to inspire those who had the honor of working alongside him. Although he is no longer with us, his contributions remain reflected in this work, which also stands as a tribute to his memory. The authors express their deepest gratitude for his dedication to research and

acknowledge that his legacy will continue to inspire future generations of anatomists and scientists.

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