

The Coronary Arteries of A Model Porcine Animal

Fernández Sánchez Andrés¹, Orbes Portilla Jairo Orlando², Martínez Niño Carlos Eduardo³, Guzmán Franco Angélica María⁴, Perez Alzate Valentina⁵, Restrepo Velarde Juan David⁶, Verónica Suaza Álvarez⁷

¹Investigative Professor in Morphophysiology, Medical Program, University Corporation Alexander Von Humboldt, Armenia, Quindío and Central Unit of Valley Cauca, Tuluá, Valley of Cauca, Colombia

²Investigative Professor, Medical Program, Technological University of Pereira

³Investigative Professor, Coordinator of Radiology and Diagnostic Imaging, University Foundation of the Andina Area, Pereira, Risaralda

⁴⁻⁶Medical Students, Seed Research in Morphophysiology and Plastination, University Corporation Alexander Von Humboldt, Armenia, Quindío

⁷Medical Students University Foundation Autonomic of Americas, Pereira, Risaralda

Abstract: *The animal models are used in basic biomedical research to explain various phenomena of both basic science and other clinical and surgical disciplines, within these bio models, porcine, has been classically used for the study of cardiovascular entities both central and peripheral, from this, the use of heart valves for exoingests and the conceptual and cardio physiological bases of interventions and hemodynamics techniques that today “save so many lives” are derived; It has also been used in studies of arrhythmia derived from occlusive coronary disease and in the management of cardiac trauma, however the basic research on the subject has not been completed, opening new horizons as new therapeutic and surgical management are developed Day by day, the present work aims to characterize the arterial vascular tree of the porcine animal model Pig Breed from the implementation of the Corrosion injection technique. It was found that this animal model meets the criteria described by the International Committee on Veterinary Gross Anatomical Nomenclature.*

Keywords: Coronary Artery, Right Dominance, Vascular Permeability, Anatomic Variation, Risk Factor for Cardiovascular Disease

1. Introduction

Animal models are used in basic biomedical investigation in order to explain many diverse phenomena within basic science while also in other clinical and surgical areas. Within these bio models, the porcine has been classically used in the study of cardiovascular entities, both central and peripheral. This produces the use of heart valves for exo grafts and the conceptual and cardio physiological bases of hemodynamic techniques and interventions that today “save so many lives”. It has also been used in studies involving arrhythmia deriving from occlusive coronary disease and in cardiac trauma management; however, the basic research on the subject has not been completed, opening new horizons as new therapeutic and surgical management are developed day by day^{1,2,3}.

From the vascular point of view, the coronary arteries are blood vessels that transport oxygenated blood and are in charge of providing irrigation to the myocardium from the cardiac cavities; they originate in the ascending aorta in the right aortic sinuses (RAS) and left aortic sinuses (LAS)^{3,4,5}. Studies conducted in the United States and Japan in porcine animals reported that the anatomic description of the right coronary artery (RCA) differs from that of the left coronary artery (LCA) in its longitude, the right is longer than the left as the right coronary artery after turning from the coronary sulcus to the cardiac cross it layers itself to become inter ventricular subsinusal (IVSS), while the left coronary artery, after a journey of a few millimeters bifurcates, or, divides into the paraconal inter ventricular (IVPC) and the circumflex (Acx)^{6,7,8}.

The nomenclature of the coronary arteries differs slightly in human medicine and veterinary medicine; for human medicine the reference of nomenclature is *Federative Committee on Anatomical Terminology*. The reference for veterinary medicine is *International Committee on Veterinary Gross Anatomical Nomenclature*. The correspondence of the following terms should be taken into account based on these references. (Table 1)

Federative Committee on Anatomical Terminology	International Committee on Veterinary Gross Anatomical Nomenclature	Description
Left Coronary Artery	Left Coronary Artery (LCA)	Left Aortic Sinus Blood Vessel
Right Coronary Artery	Right Coronary Artery or Right Circumflex Artery (RCA)	Right Aortic Sinus Blood Vessel
Interventricular Artery or Anterior Descending	Inter Ventricular Paraconal Artery (PIA)	Left Coronary Artery Blood Vessel
Interventricular Artery or Descending Posterior	Subsinusal Interventricular Artery (SIA)	Blood Vessel Originating From Either Coronary Artery
Circumflex Artery	Circumflex Artery or Left Circumflex Artery (Acx)	Left Coronary Artery Blood Vessel

According to the nomenclature previously mentioned in Table 1; the RCA, SIA, PIA, and ACx angiogenically produce branches which extend and introduce the myocardium of the ventricles because of the greater thickness that they have in comparison to the Atria. In this way, the anterior face of the left ventricle is irrigated by

diagonal branches (DB) of the (PIA). The lateral faces of the left and right ventricles are irrigated by right marginal branches (RMB) pertaining to the RCA and the left marginal branches (LMB) corresponding to the ACx respectively; the inferior side of the left ventricle by lateral posterior branches (LPB) ^{7,8,9} can be described in a variant way by the intermedius ramus (IR), when the left coronary artery (LCA) divides and locates itself in the PIA and ACx, becoming a primary diagonal branch (DB) ¹⁰.

In anthropogenic terms, the model of human coronary dominance has been based upon the findings of various authors ^{11, 12, 13}, recognizing the work of Dr. Schlesinger ¹⁴ who established the reference towards right coronary dominance when the RCA, after originating the posterior inter ventricular portion (inter ventricular subsinusal portion in animals) it extends to below the coronary sinus and produces the lateral posterior branches (LBP) and finalizes as the posterior inter ventricular portion; the concept of co dominance or balanced circulation is applied when the lateral posterior branches originate from the ACx and the RCA and finishes as a posterior inter ventricular portion ^{13,14}.

The purpose of the present study is to value the anatomical characteristics such as origin, ramification, caliber and dominance of the coronary porcine arteries and to them compare them to those of human coronary arteries in order to determine their similarities, and in this manner conclude if the most common pig heart is a valid model that can be extrapolated for dissection and anatomic study in human medical programs.

2. Materials and Methods

A descriptive study was conducted where an injection corrosion technique was applied with the purpose of verifying coronary dominance and the cardiac vascularity distribution pattern, using 30 specimens of porcine hearts of the PIG breed destined for sacrifice, provided by the company FrigoTimaná, Tuluá, Cauca Valley.

Management and Conservation and the Specimen

The hearts were initially washed with a commercial chemical substance meant for corpse preservation composed of formaldehyde and aldehyde ketones with the purpose of eliminating blood waste and clots of atrial and ventricular cavities and large blood vessels. The next step was the dissection of the pulmonary artery and aorta. They were sectioned transversally on top of the root at semilunar valve depth. The right and left coronary sinuses were identified and the right and left coronary arteries were cannalized, using a number #6 Nelaton probe, through which a self-curing acrylic solution along with its respective dissolvent was manually injected while being mixed with red paint within a 1- minute interval and the plunger of a 20ml needle in order to observe repletion and coloration in the lumen of the RCA, right margins, PIA, LCA, RD, ACx, left margins, lateral posterior branches, and RI if it is present.

The points of origin of the RCA, LCA, SIA and posterior lateral branches were classified as normal and varying; the amount RD, RMI and LPB were quantified. Coronary dominance was determined according to Schlesinger standards ¹³. Measures of central tendency and dispersion were also calculated to determine the points of origin of the RCA, LCA, PIA, and ACx.

3. Results

In accordance to the 100% of the sample used, the arteries demonstrated a normal anatomical origin, meaning the RCA found in the ostium in the right aortic cavity. The LCA found in the ostium from the left aortic cavity, the PIA and ACx of the LCA. The RI was found in 12% of hearts (Figures A and B). The average vascular diameter was greater in the LCA with 6.0mm and the smallest was the ACx with 5.02 mm.

The average longitude of the LCA was 9.14mm, with a range of 5.16 and 13.25, a standard deviation of 2.98 and a variance of 9.14mm. It was observed that many secondary ramifications followed from the RCA and LCA, generating a very dense vascular pattern inside the myocardium, a positive aspect which generates good collateral irrigation and myocardial micro circulation.

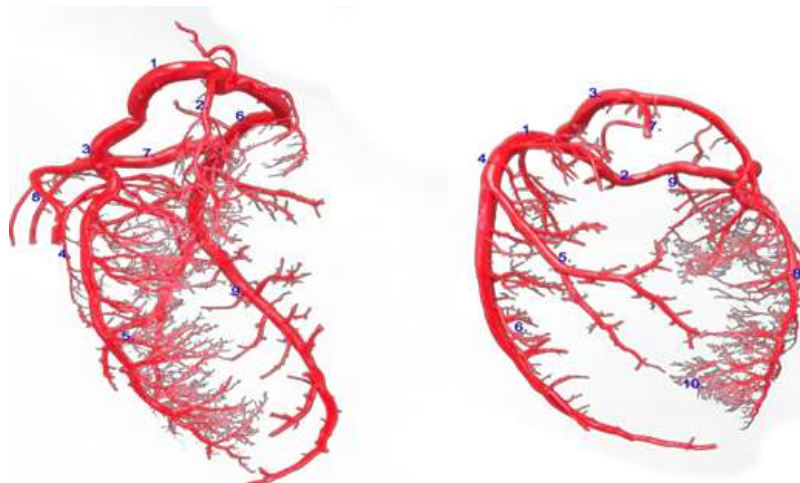


Photo Nro. Post Lateral View.

1. Right coronary artery; 2.Right marginal branch;3.Posterior inter-ventricular branch;4.Atrial branches; 5.Inter-ventricular branches; 6. Left coronary artery; 7.Circumflex branches;8.Posterior left ventricle branches; 9.Anterior inter-ventricular branches.

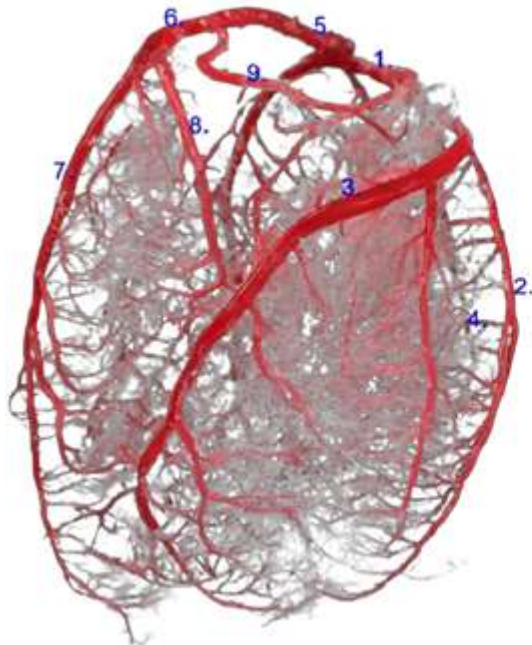


Photo Nro.2.Front Left Side View.

1. Left coronary artery; 2.Right coronary artery; 3. Circumflex branch; 4. Anterior inter-ventricular branch; 5.Lateral branch; 6. Septal inter-ventricular branches; 7. Left marginal branch; 8. Posterior inter-ventricular branch; 9.Right marginal branch; 10. Septal inter-ventricular branches

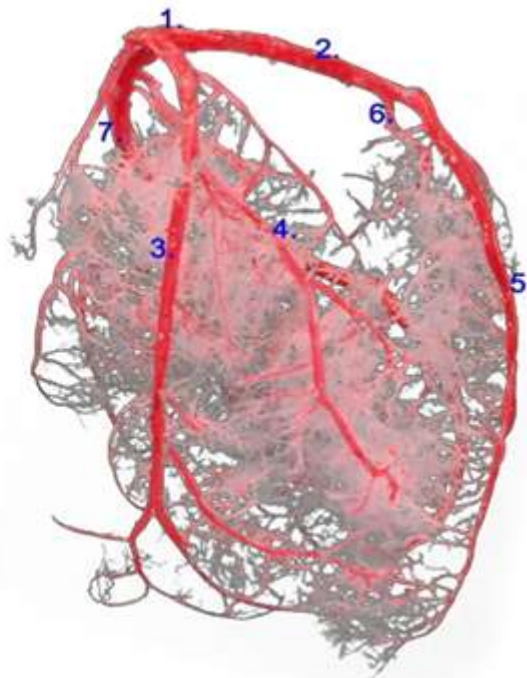


Photo Nro. 3Left Post Lateral View.

1. Right Coronary artery; 2.Posterior inter-ventricular branch; 3.Side right branch; 4.Septal inter-ventricular branches; 5.Left coronary branch; 6. Circumflex branch; 7.Left marginal branch; 8.Posterior left ventricle branch; 9.Cone Arteriosus branch

Photo Nro. 4. Anterior View.

1. Left coronary artery; 2. Circumflex branch; 3.Anterior ventricular branch; 4.Lateral branch; 5.Left marginal branch; 6. Posterior left ventricle branch; 7. Right coronary artery

4. Discussion

In the past years, the pig has been used as a model for bio medical experimentation and surgery. It also serves as an anatomy reference in comparison to humans because it's morphological expression as a cardiac level is nearly identical. Reports about porcine coronary circulation is scarce nevertheless, those that do exist conclude that the anatomical pattern of origin, distribution and ramification of coronary arteries in pigs are similar to those of humans.^{15,16}

Descriptive anatomical studies of coronary arteries have been widely conducted in humans using diverse techniques like direct dissection and a diagnostic imaging methods like cardio resonance, angiotomography with multi-detectors and coronary angiographs^{17,18}.

Recently, in Colombia direct studies by human cadaver hearts age become complicated and difficult because of restrictions of legal character using descriptive studies and

case reports based on imaging studies which are part of the users clinical history.^{19,20}

Many experimental bio models like the laboratory rat, the albino rat and the guinea pig among others used in bio medical investigation have demonstrated analogies with those conducted in humans. The pig as an experimental bio model has been used for a little less than two decades, in laparoscopic surgery simulation, endoscopic simulation and traumatology^{21,22}; it has also been used in cardiac transplant with genetic bio model modification in other mammals like the baboon because of its dimensions and morphological characteristics which are very similar.^{23,24,25}

5. Conclusions

The porcine coronary arteries like human arteries are very similar in relation to the anatomical origin, ramification pattern, and dimensions and dominance. This contributes to the pig being a highly compatible experimentation animal with human coronary morphology.

The pig's most common coronary dominance system is right followed by the left and a balanced circulation or co dominance, which are also the conclusions drawn by reports of descriptive studies conducted in human coronary arteries. When the ramus intermedius is found, it resembles the first left marginal branch and not like the first diagonal branch which is how it has usually been expressed in anatomy texts and in the findings of descriptive studies.

Thanks

The authors would like to the the company FrigoTimana, from Tulua, Cauca Valley. A very special thanks to the engineer Daniel Rojas, Property manager of said company for its collaboration in investigation processes from the Health Faculty of the Central Unit of the Cauca Valley. The authors would also like to thank the Morphology Laboratory of the Central Unit of the Cauca Valley attached to the Medical Program.

References

- [1] Zuñiga Jesus, Tur Mary Joseph, Silvana N, Miloco. Science and Animal Experimentation 1. Edition. Editorial Mc Graw Hill - Interamericana. 2001. Surgical Experimental Procedures. PP: 361-513.
- [2] Von Hoosier G, The age of biology: opportunities and challenges for Laboratory Animal Medicine. Scand J LabAnimSci 1999; 26 (4):176-184
- [3] Institutional Animal Care and Use Committee Guidebook. 2nd ed. Office of Laboratory Animal Welfare. National Institutes of Health Department of Health and Human Services. Bethesda, MD. 2002; p.210.
- [4] Feneis Illustrated anatomical nomenclature. Fifth edition. Elsevier Masson: Spain; 2007
- [5] Sarria S, Artech E, Certo M, Fernández G. Valoración mediante TC multidetector de las variantes anatómicas de las arterias coronarias. ColombMed. 2007;38(3):263-73.
- [6] International Committee on Veterinary Gross Anatomical Nomenclature. Nómina Anatómica Veterinaria. Quinta edición. Editorial Committee Hannover (Alemania), Columbia (Estados Unidos), Ghent (Bélgica) and Sapporo (Japón); 2012. (Consultado: 18 de Junio de 2015) Disponible en: http://www.wava-amav.org/Downloads/nav_2012.pdf
- [7] König H, Liebich H. Anatomía de los animales domésticos, tomo 2, órganos, sistema circulatorio y sistema nervioso. Texto y atlas es color. Segunda edición. Editorial Médica Panamericana: España; 2008.
- [8] Pérez W, Lima M. Distribución de las arterias coronarias en el Rinoceronte Blanco (*Ceratotherium simum*). Int J Morphol. 2010;28(3):811-4.
- [9] Ryan S, McNicholas M, Eustace S. Anatomical Radiology. Editorial Marbán: Spain; 2013.
- [10] Tsioufis K, Latsios G, Tousoulis D, *et al.* Anomalous common origin of all coronary arteries with a common ostium from the left sinus of Valsalva. Int J of Cardiol. 2010; 139:47-9. DOI: <http://dx.doi.org/10.1016/j.ijcard.2008.11.024>.
- [11] Kosar P, Ergun E, Öztürk C, *et al.* Anatomic variations and anomalies of the coronary arteries: 64-slice CT angiographic appearance. Diagn Interv Radiol. 2009; 15(4):275-83. DOI: 10.4261/1305-3825.DIR.2550-09.1.
- [12] Paolillo V, Gastaldo D, Vaudano G. An unusual course of the ramus intermedius shown by multislice computed tomographic coronary angiography. Tex Heart Inst J. 2006; 33(3):406-7.
- [13] Godwa R, Rahmatullah S, Khan I. Myocardial bridging of the ramus intermedius coronary artery. Int J Cardiol. 2003; 89:295-6. OI: [http://dx.doi.org/10.1016/S0167-5273\(02\)00465-5](http://dx.doi.org/10.1016/S0167-5273(02)00465-5).
- [14] Ballesteros L, Corzo E, Saldarriaga B. Determinación de la dominancia coronaria en población colombiana. Un estudio anatómico directo. Int J Morphol. 2007;25(3):483-91.
- [15] Schummer, A.; Wilkens, H.; Vollmerhaus, B. y Habermehl, K.H. 1981. The anatomy of the domestic mammals. Volume 3. The circulatory system, the skin, and the cutaneous organs of the domestic mammals. Verlag Paul Parey. Berlin. 610 pp.
- [16] Loukas M, Curry B, Bowers M, Louis R, *et al.* The relationship of myocardial bridges to coronary artery dominance in the adult human heart. J Anat. 2006; 209(1):43-50. DOI: 10.1111/j.1469-7580.2006.00590.x.
- [17] Angelini P. Coronary artery anomalies current clinical issues. Definition, classification, incidence, clinical relevance and treatment guidelines. Tex Heart Inst J. 2002;29(4):271-8
- [18] Rodríguez J, Turienzo E, Vigal-Brey G, Brea-Pastor A. Surgical training with simulators in training centers. Cir Esp. 2006; 79 (6): 342-8.
- [19] Balén EM, Sáez MJ, Cienfuegos JA, *et al.* Anatomy of the pig applied to the experimentation in general surgery. Cir Esp. 2000; 67: 586-93.
- [20] Navas-Aparicio M, Mora-Mesén C, Rojas-Madrigal A, *et al.* Practical guide for dissection and identification of anatomical structures at facial level in a porcine animal. Rev Esp Circ Oral Maxilofac. 2013; 35 (2): 69-73.
- [21] Gómez FA, Ballesteros L. Anatomic study of the right coronary artery in pigs. Feature review in comparison with the human artery. Int J Morphol. 2013; (4):1289-96.20.
- [22] Crick S, Sheppard M, Ho S, *et al.* Anatomy of the pig heart: comparisons with normal human cardiac structure. J Anat. 1998; 193:105-19. DOI: 10.1046/j.1469-7580.1998.19310105.x.
- [23] World Health Organization. Basic epidemiology and health surveillance. Modules of basic epidemiology and health surveillance. Module 2, types of epidemiological studies. Second edition. Argentina; 2004
- [24] Ugalde H, Ramirez A, Ugalde D, *et al.* Abnormal birth of the coronary arteries in 10,000 adult patients undergoing coronary angiography. Rev Med Chile. 2010; 138: 7-14.