



Research on the Distribution of Coronary Arteries in Pig (*Sus Scrofa Domesticus*)

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RESEARCH ARTICLE

Abstract

Pigs are some of the most widely used experimental models, an advantage being the characteristics of homeostasis and many morphological features comparable to those in humans. For this reason, we addressed this topic in this paper, with the major objective of completing the data and even identifying some features not described in the literature. The present study was performed on 20 pig carcasses, with different weights and ages (2-4 months). The aim was to highlight some peculiarities regarding the coronary artery system in this species, using as a method the injection of vessels with contrasting plastic material. The collaterals and terminals of the coronary arteries, their distribution territories as well as the identified individual variants were described. As a general conclusion, regardless of the polymorphism in all dissected cases, the left coronary artery was the dominant artery, there being no exception from the data known in the literature.

Keywords: heart; swine; coronary arteries.

INTRODUCTION

When discussing the species *Sus scrofa domesticus*, the sphere of interest of the subjects is at the center of the animal as a food source. However, the pig is now recognized as a non-rodent animal model, widely used in biomedical research (Swindle and Smith, 2015). Moreover, the species is particularly important for experiments aimed at xenotransplantation of organs in humans (Murthy et al., 2016). Numerous studies show that the possibility of transplanting the heart from pigs into patients in the last stage of heart failure would solve the problem of critical lack of organs from human donors (Roth and Tuggle, 2015; Sahni et al., 2008). To highlight the importance of the species as an experimental model in cardiology, we mention that in a table which lists 9 experiments in cardiothoracic surgery on animals, conducted by different authors between 1964 and 1997, on four species used (pig, sheep, chimpanzee, baboon), 50% of these focused on the use of pig heart (Allender et al., 2008), xenotransplantation of organs in humans (Murthy et al., 2016). Although the macro- and microstructure aspects of the pig heart are relatively well represented by the literature (Barone, 1996; Carp, 2002; Damian, 2001; Carp, 2002), we considered that we can contribute by describing the individual variants encountered by us in this study to the completion in some measure of mapping the trophic circulatory system of this organ.

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MATERIALS AND METHODS

The present study was performed on 20 pig cords, from animals with different weights and ages (2-4 months). The aim was to highlight some features of the coronary artery system in this species. The research was carried out in the discipline of Anatomy within the University of Agronomic Sciences and Veterinary Medicine Bucharest. The cords were harvested from animals of common breeds. Using dissection techniques, step by step, the opening of the aortic bulb was followed, where the original orifices of the cardiac arteries - left and right coronary arteries were highlighted. After highlighting them, we inserted a catheter into the lumen of the coronary arteries, the right coronary artery, followed by the left coronary artery, after which we injected into the lumen of the vessel the contrast agent AGO, which was stained with red pigment. After injection of the contrast agent, the cords were placed in water with 10% formalin for approximately 24 hours to achieve fixation. The dissection was performed after 24 hours, where gradually, also took segmental photos.

The identification, description and homologation of the formations were performed according to the Veterinary Anatomical Nomination - 2017.

RESULTS AND DISCUSSIONS

Topography and distribution of the left coronary artery

The left coronary artery detaches dorsally from the left crescent valve of the aortic orifice. Originally, it has an average diameter of 4 mm and is larger than the right coronary artery. It is ventral to the left atrium, between the left atrium and the trunk of the lungs. Once in the coronary groove, the left coronary artery divides into two strong branches: the interventricular paraconal branch (placed in the eponymous groove) and the left circumflex branch (which runs through the coronary groove caudally and then to the left. The paraconal branch is generally more voluminous and only four out of 20 specimens had an equal diameter.

The interventricular paraconal branch has a slightly sinuous trajectory, following the paraconal groove (Figure 1). In almost all cases (18 out of 20), it reaches almost half of the cranial edge of the right ventricle and then bends obliquely to the right (atrial) part of the ventricular mass. Three categories of collateral branches can be recognized: right ventricular, left ventricular and left septal.

The smallest are the straight ventricular branches. They are distributed to the wall of the right ventricle, immediately in the area near the paraconal groove. Intended for the arterial cone, the first branch of this category is called the left branch of the arterial cone, although in this species it comes to approach this structure only exceptionally (15% of cases).

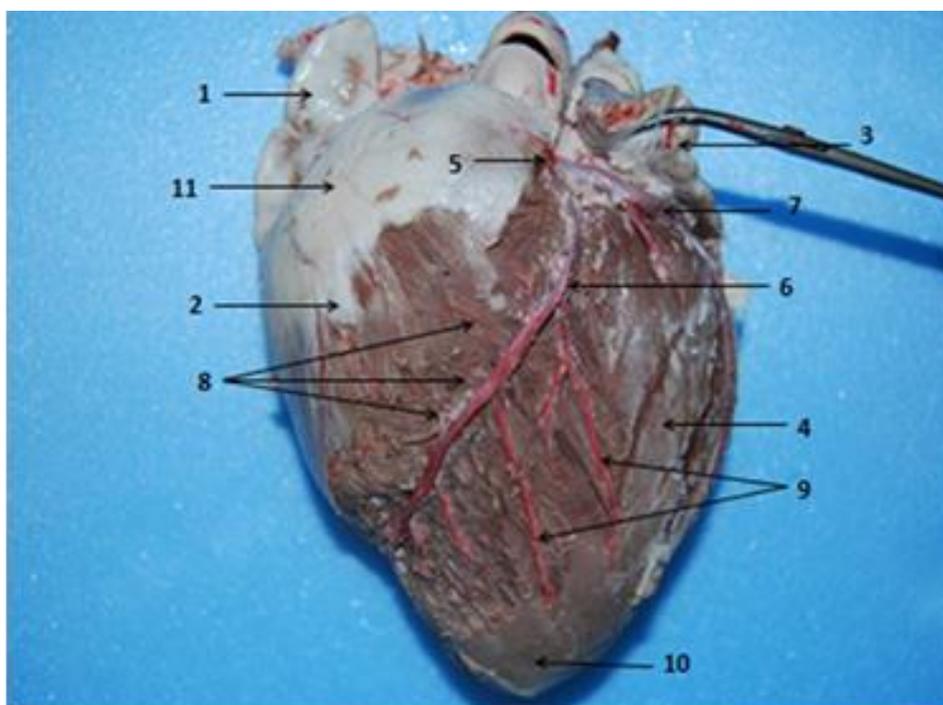


Figure 1. Left coronary artery terminals in pigs (original)

1-right atrium; 2-right ventricle; 3-left atrium; 4-left ventricle; 5-left coronary artery; 6-interventricular paraconal branch; 7- left circumflex branch; 8-collateral ventricular straight; 9-left ventricular collateral; 10-apex

The second category of branches - left ventricular, much better represented compared to the first, descends obliquely, parallel to the myocardial fibers, to the caudal edge of the left ventricle (Figure 2-2).

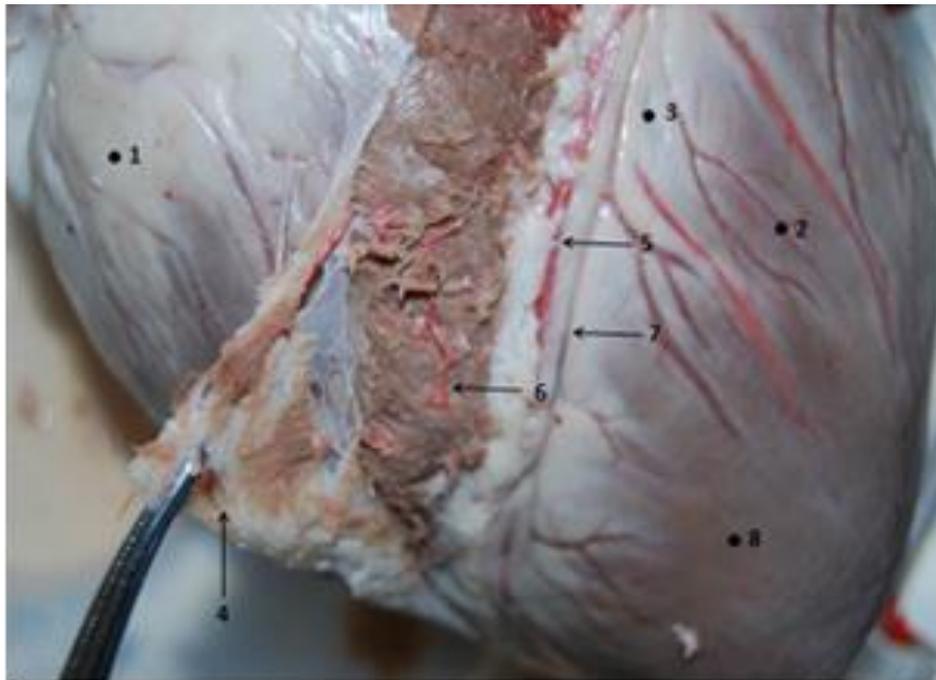


Figure 2. Collateral of the paraconal branch in the segmentdistal path (original); 1-right ventricle; 2-left ventricular branches; 3-adipose tissue in the paraconal interventricular groove; 4-epicardium; 5-paraconal branch covered with adipose tissue; 6- straight ventricular branches; 7-large cardiac vein; 8-left ventricle

The left septal branches are short, uniform but numerous. Destined for the interventricular septum, they are very branched, which makes them cover a wider distribution territory than the straight ventricular branches. The interventricular septal branch is the first left septal branch, the best represented of them and appears at the origin of the left coronary artery. It runs obliquely along the wall of the ventricle towards the apex, serving the dorsal and middle areas of the interventricular septum. Other left septal branches serve the left peripheral portion, near the paraconal groove. Very rarely, the interventricular septal branch was absent, tributary territory from the septum being irrigated in these cases by the atrio-ventricular branch (originating in the right coronary artery). Exceptionally (5% of cases) two interventricular septal branches were present. With the exception of the septal distribution, the interventricular septal branch provides an integrated trabecular branch to the second-order pillar (septo-marginal trabeculae). This relatively small branch was identified in 65% of subjects. In 10% of the pieces, the branches of the straight coronary artery also contribute to the irrigation of the septo-marginal trabeculae.

The left circumflex branch, initially masked by the edge of the left atrium, is placed, as mentioned in the coronary groove. In the path it emits collateral branches then it is exhausted at the origin of the subsinuous groove. Collateral branches can be classified into two categories: atrial and ventricular. From the point of view of origin and distribution, the atrial branches are: proximal (located on the auricular surface); intermediate (close to the left edge) and distal (on the surface of the atrium itself).

The proximal branches destined for the left atrium are best represented among the atrial branches. The first of these is the largest. They mainly serve the left atrium, the dorsal surface of the left atrium and also the pulmonary veins. At 20% of the pieces, the proximal branch bifurcated: its two subdivisions reached the left atrium, respectively in the caudal part of the right atrium, interatrial septum and the terminus of the caudal vena cava. Most often there is only one intermediate atrial branch. Absent sometimes, it can be replaced by other branches of the circumflex artery. Its territory is the most caudal area of the left atrium. In 40% of the heart, it contributes to the irrigation of the pulmonary veins. The distal atrial branches are the thinnest and shortest atrial branches. They spread to the base of the atrium, but can also reach dorsally to the pulmonary veins or to the caudal vena cava and the interatrial septum.

Much better represented, the left ventricular branches are of two types: proximal and distal to the edge of the left ventricle. The proximal branches of the left ventricle are relatively long. It is oriented obliquely towards the caudal edge and the apex of the heart, irrigating the most dorsal area of the auricular surface of the left ventricle (Figure 3-7).

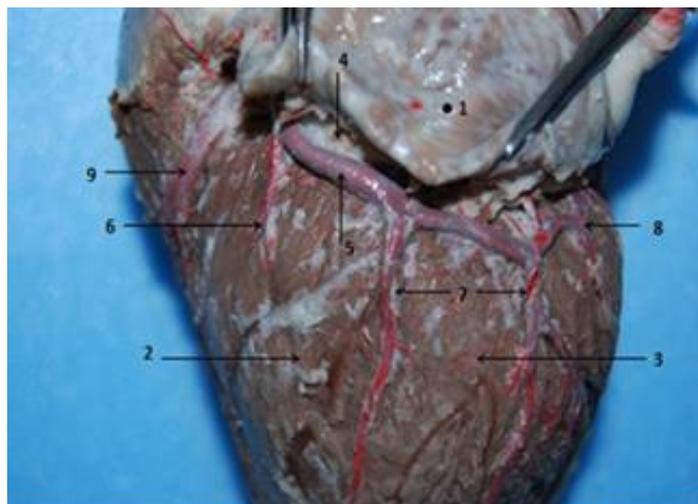


Figure 3. Path of the left circumflex branch in pigs (original); 1-left atrium; 2-left ventricle - lateral face; 3-left ventricle - caudal margin; 4-left atrioventricular groove; 5- left circumflex branch; 6-basilar collateral branch of the left ventricle; 7-proximal branches of the left ventricle; 8-terminals of the left circumflex branch; 9- interventricular paraconal branch

The branch for the ventricular margin follows the caudal edge of the heart to the apex, but never reaches this place. In 15% of cases it seems to be an extension of the left circumflex branch itself. When this branch is missing, the left ventricular edge receives collaterals of the proximal branch of the left ventricle. The distal branches of the left ventricle are usually short and thin and serve the wall of the left ventricle, between the edge of the left ventricle and the subventricular interventricular groove, ie the atrial surface of the left ventricle. In 25% of cases, one of these branches is wider, as if continuing and ending the left circumflex branch.

Topography and distribution of the right coronary artery

The right coronary ostium is located on the right side of the aortic bulb sinus, above the right crescent valve. Exceptionally (5% of cases) there may be two coronary ostia. The right coronary artery passes between the right atrium and the base of the pulmonary trunk, the right coronary artery runs to the right the coronary groove, to the origin of the subsinusal groove (Figure 4).

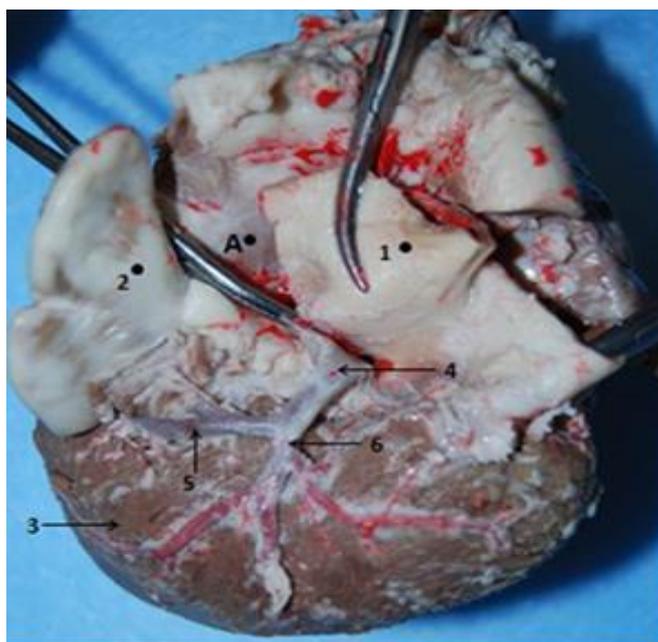


Figure 4. Terminal branches of the right coronary artery in pigs (original); 1-aortic artery - the area of the aortic bulb; 2-right atrium (high); 3-base of the right ventricle; 4-origin of the right coronary artery; 5-trajectory of the right coronary artery in the atrio-ventricular groove; 6-branch of the right ventricular margin

It is usually the same length as the left circumflex branch. When one of these branches is shorter, the other compensates for its difference in length. Once it reaches the level of the subsinuous interventricular groove, the right coronary artery gives rise to a short atrio-ventricular branch, for the septum that continues as the interventricular subsinuous branch, which descends through this groove. Like the left circumflex branch, the right coronary artery gives two types of branches intended for the right atrium and the wall of the right ventricle.

Very thin, straight atrial branches have an ascending path. The first, called the proximal branch of the right atrium, is usually larger. It can even be double. When it is absent it is compensated by other branches. It serves the right atrium and in most cases rises dorsally between this atrium and the aortic wall, to be distributed to the cranial vena cava (50% of cases), the pulmonary veins (30% of cases) and the caudal vena cava (20% of cases). At 5 cords the interatrial septum receives branches from the same source. The intermediate atrial branch is also single or double. It is distributed on the cranial wall of the right atrium, sometimes reaching the auricle. In some cases, (20%) it is oriented towards the cranial wall of the aorta, giving branches and the cranial vena cava. The atrial distal branches are very thin. It is distributed over the base of the right atrium and, in 8 cases, will irrigate the cranial vein. The right ventricular branches are better represented than the atrial ones, but not as much as the left ventricular branches. The right branch of the arterial cone, unlike the left one, is easier to identify, serving the right side of this structure.

The proximal branch of the right ventricle is slightly larger than the branch of the arterial cone, serving the left surface of the right ventricle. In 35% of cases, these two branches start in the common trunk of the right coronary artery. The branch of the right ventricular margin is wide and often double (Figure 4-6). It extends to the top of the heart, but it does not reach it. The distal branches for the right ventricle, usually multiple (Figure 5-7), not very well represented, serve a small area, between the edge of the right ventricle and the subsinusal groove, ie the most dorsal part of the right ventricular wall, on the atrial surface.

As shown in the Figure 5, the right coronary artery gives rise to an atrio-ventricular branch before continuing as a subsinusal branch in the groove of the same name. It is very small but usually easy to identify (except for two cords where it could not be distinguished from other straight septal branches). The atrio-ventricular branch turns medially to the septum and/or continues caudally for a short distance in the coronary groove. It divides into two or three thin branches to participate in the irrigation of both the interventricular and interatrial septum, but also a small part of the dorsal wall of the left ventricle, near the coronary groove. In 10% of cases it gives a branch to the caudal vena cava.

The interventricular subsinusal branch is wider and represents the continuation of the right coronary artery in the corresponding groove. It ends near the apex (Figure 5). It is constantly shorter than the paraconal branch. In fact, its length is inversely proportional to that of the paraconal branch.

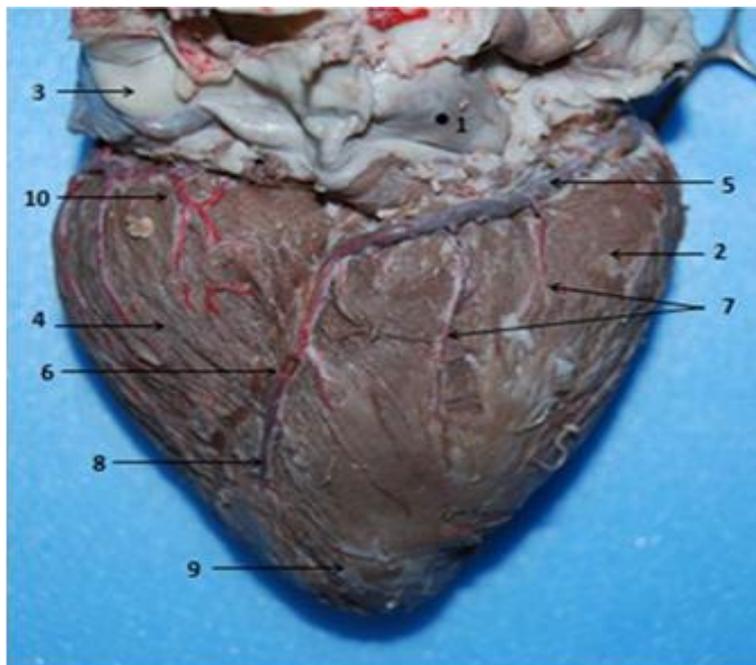


Figure 5. Terminal segment of the right coronary artery (original)

1-right atrium; 2-right ventricle; 3-left atrium; 4-left ventricle; 5-right coronary artery; 6-subsinusal - interventricular branch of the right coronary artery; 7-distal branches for the right ventricle; 8-terminal path segment of the subsinusal branch; 9-apex area; 10-terminals of the left circumflex artery

Like the interventricular paraconal branch, the subsinusal branch gives rise to three types of arteries: straight ventricular branches, left ventricular branches and straight septal branches. The right ventricular branches are usually best represented and are oriented obliquely towards the right ventricular edge, irrigating the right ventricular wall. The left ventricular branches are shorter and thinner. They face the left ventricle. In most cases they have a distal origin in the interventricular subsinusal branch. Proximally the dorsal wall of the left ventricle is served by the distal ventricular branches (50% of cases) but divisions of the atrio-ventricular branch may also participate. The straight septal branches are more uniform and numerous. They enter the interventricular septum to irrigate the right peripheral portion. They are short and branched, it's like the ones on the opposite side, straight septal branches.

CONCLUSIONS

From a macroscopic point of view, the following conclusions can be drawn:

1. In pigs, the myocardial volume served by the left coronary artery is higher compared to that served by the right coronary artery, which is why it is considered dominant.
2. The coronary arteries detach from the aortic bulb, according to the classical norm described in the literature somewhat similar to those in humans.
3. The left coronary artery is very short and divides into an interventricular paraconal branch and a left circumflex branch. They give branches intended mainly for the atrium and left ventricle.
4. The paraconal branch gives rise in the proximal part to an interventricular septal branch that is distributed to the largest area of the dorsal and central part of the septum.
5. The right coronary artery serves mainly the right atrium and ventricle and continues constantly as a subsinusal interventricular branch.
6. The atrio-ventricular branch of the right coronary artery irrigates a small part of the dorsal interventricular septum, especially on the right side.

Author Contributions: GZ designed the study, wrote the working protocol and performed the statistical analysis. CRB wrote the draft of the manuscript and completed the manuscript. AD, SMR and GC collected the samples. ID processed and dissected the samples. MD, SAM and DCC managed the searches in the specialized literature and organized the material.

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Conflicts of Interest

The authors declare that they have no competing interests.

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